NAVAL
POSTGRADUATE
SCHOOL

MONTEREY, CALIFORNIA

THESIS

HASTILY FORMED NETWORKS (HFN) AS AN ENABLER FOR THE EMERGENCY RESPONSE COMMUNITY

by

Oscar D. Antillon

March 2012

Thesis Advisor:	Brian Steckler
Second Reader:	Frank Barrett

Approved for public release; distribution is unlimited

THIS PAGE INTENTIONALLY LEFT BLANK

13. ABSTRACT (maximum 200 words)
The effects of natural or manmade disasters in communications infrastructures are so severe that immediately after the disaster the emergency responders are unable to use them. In addition, some areas do not have any useful infrastructure at all. To bridge this gap in communications, a need exists for a reliable technology not dependent on the existing infrastructure.
This thesis focuses on first identifying the problem of communications gaps during natural or manmade disasters and reviewing the impact and potential benefit of implementing a solution based on the Hastily Formed Networks (HFN) model. The research explores the different technological solutions to solve this problem by evaluating documentation for commercial off-the-shelf technologies (COTS). Additionally, the thesis reviews the results of field experimentation conducted to evaluate the performance of these technologies in the field. The ultimate goal is to introduce the HFN concept as an enabler for the Emergency Response Community (ERC).
Throughout this research, the focus revolves around testing COTS technologies. The research provides emergency responders with the background knowledge to make decisions on how to best bridge the gap of lack of communications under austere environments, and therefore enable them to provide better response.

i

THIS PAGE INTENTIONALLY LEFT BLANK

**HASTILY FORMED NETWORKS (HFN) AS AN ENABLER
FOR THE EMERGENCY RESPONSE COMMUNITY**

Oscar D. Antillon
Lieutenant Commander, United States Navy
B.S., University of Utah, 1998

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN INFORMATION TECHNOLOGY MANAGEMENT

from the

**NAVAL POSTGRADUATE SCHOOL
March 2012**

Author: Oscar D. Antillon

Approved by: Brian Steckler
                Thesis Advisor

                Frank Barrett
                Second Reader

                Dan C. Boger
                Chair, Department of Information Sciences

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

The effects of natural or manmade disasters in communications infrastructures are so severe that immediately after the disaster the emergency responders are unable to use them. In addition, some areas do not have any useful infrastructure at all. To bridge this gap in communications a need exists for a reliable technology not dependent on the existing infrastructure.

This thesis focuses on first identifying the problem of communications gaps during natural or manmade disasters and reviewing the impact and potential benefit of implementing a solution based on the Hastily Formed Networks (HFN) model. The research explores the different technological solutions to solve this problem by evaluating documentation for commercial off-the-shelf technologies (COTS). Additionally, the thesis reviews the results of field experimentation conducted to evaluate the performance of these technologies in the field. The ultimate goal is to introduce the HFN concept as an enabler for the Emergency Response Community (ERC).

Throughout this research, the focus revolves around testing COTS technologies. The research provides emergency responders with the background knowledge to make decisions on how to best bridge the gap of lack of communications under austere environments, and therefore enable them to provide better response.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS AND ABBREVIATIONS

ACU   Antenna Control Unit
AMSP   Andrew Molera State Park
AOR   Area of Operations
APAN   All Partners Access Network

BC   BreadCrumb®
BCWN   BreadCrumb® Wireless Networks
BGAN   Broadband Global Area Network
BPI   Business Process Integration
BPS   Business Process Standardization

C2   Command and Control
CALEMA   California Emergency Management Agency
CHD   Complex Humanitarian Disaster
CHE   Complex Humanitarian Emergency
CHSC   Container Handling System Corp
CIV-MIL REL   Civil-Military Relations
CMOC   Civil-Military Operations Center
COP   Common Operational Picture
COTS   Commercial Off-the-Shelf

DENCAP   Dental Civic Action Program
DISA   Defense Information System Agency
DJC2   Deployable Joint Command and Control
DoD   Department of Defense
DOD INST 3000.05   DoD Procedures for Management of Information

EMP   Electromagnetic Pulse
EOC   Emergency Operations Center
ERC   Emergency Response Community

FLAK   Flyaway Kit
FLIR   Forward Looking infrared
FOBS   Field Observer Teams
FRS   Family Radio Service

GAR   General Assessment Report
GUI   Graphical User Interface

HA/DR   Humanitarian Assistance/Disaster Relief
HFN   Hastily Formed Networks

IEEE	Institute of Electrical and Electronics Engineers
ICT	Information and Communications Technologies
IGO	International Government Organization
IHC	International Humanitarian Community
IO	International Organizations
IP	Internet Protocol
IPC3	Independently Powered Command/Control/Communication Program
ISDN	Integrated Service Digital Network
ITACS	Information Technology and Communications Services
JCSC	Joint Communications Support Command
JCSE	Joint Communications Support Element
JTF	Joint Task Force
Kbps	Kilobits per Second
LMR	Land Mobile Radio
LOFR	Liaison Officer
LOS	Line of Sight
Mbps	Megabits per Second
MCIP	Multinational Communications Interoperability Program
MEDCAP	Medical Civic Action Program
MIB	Management Information Base
NAS	Network Attached Storage
NDU	Network Data Unit
NERV	Network Emergency Response Vehicle
NGO	Non-Governmental Organization
NICS	Next-Generation Incident Command System
NOC	Network Operating Center
NPS	Naval Postgraduate School
NRF	National Response Framework
OEM	Office of Emergency Management
OES/EMA	Office of Emergency Services/Emergency Management Agency
OFDM	Orthogonal frequency division multiplexing
OSD	Office of the Secretary of Defense
OSI	Open Systems Interconnection
PCoIP	PC over IP

PSAP	Public Safety Answering Point
RIOS	Radio Interoperability System
RRK	Rapid Response Kit
SAR	Satellite Access Request
SATCOM	Satellite Communications
SIM	Subscriber Identity Module
SOTM	Satellite on the Move
SSTR	Security, Stability, Transition, Reconstruction
TELEMED	Telemedicine
U.S.	United States
UN	United Nations
UN-OCHA	United Nations-Office for the Coordination of Humanitarian Affairs
US-AID	United States Agency for International Development
VoIP	Voice over Internet Protocol
VPN	Virtual Private Network
VSAT	Very Small Aperture Terminal
VTC	Video Teleconference Center
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WTC	World Trade Center
WWW	World Wide Web

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGMENTS

THIS PAGE INTENTIONALLY LEFT BLANK

I   INTRODUCTION

Immediately after a natural or manmade disaster, the communications infrastructures are often degraded to the point that emergency responders are unable to use them. In addition, some areas do not even have any useful infrastructure at all. In situations in which collaboration among responders is well established, the obstacle is communications, "Cooperation without information is not sufficient to increase response efficiency" (Comfort, Ko, & Sagorecki, 2004). To bridge this gap in communications, a need exists for a reliable technology not dependent on the existing infrastructure. Hastily formed networks concepts provide the ability to communicate without the need for existing infrastructure by utilizing current wireless technologies including Satellite (VSAT/BGAN), Meshed Wi-Fi, WiMax, and Cellular to establish a network that emergency responders can use.

The local community often lacks the technical capability to develop and implement a reliable communications infrastructure to support its needs during disasters. By researching and identifying the possible solutions to this problem, the local community may receive better response during a disaster.

This case study can have a national impact by identifying the best practices both in technologies used and business practices for the procurement maintenance and pool sharing of these resources. The best practices and the lessons learned are the basis for a model that can be replicated at all emergency response communities (ERC) in the United States. The process will augment the existing communications infrastructure, and therefore, enhance the emergency response to natural or manmade disasters.

A.   PROBLEM STATEMENT

In disasters in which the existing communications infrastructure is destroyed or no infrastructure exists to begin with, state and local emergency responders lack the capability to coordinate their resources and to enable a

better response to the disaster. To enable a better response and better use of resources, new processes and technological solutions are necessary to fill this gap in communications.

B.   PURPOSE STATEMENT

The goal of this thesis is to develop a model for local communities to analyze the different options local responders have available during a disaster in which the communications infrastructure is damaged or not available, and to evaluate the use of the Hastily formed Networks (HFN) concepts to enhance their ability to communicate during these events.

The result of the research is a model for local emergency responders. This model provides the best practices for procurement, maintenance, training and pool sharing for the local ERC. The thesis runs in parallel with a Department of Homeland Security (DHS) and Science and Technology directorate Naval Postgraduate School (NPS) Hastily Formed Networks project to develop a model for the best technologies available to implement hastily formed networks for counties around the country.

C.   BACKGROUND

Studies of recent disasters point to the critical need for reliable means of communications immediately after a disaster. In every disaster, the ability to respond quickly to save lives and property improves with reliable communications infrastructure. As a result of the disasters from the last decade, the critical need for a reliable form of communications has become a top priority, and it is one of the most elusive targets across the ERC.

NPS coined the term HFN and created the center with that name with the purpose of enhancing the cooperation between the ERC, Non-Government Organizations (NGOs), civilian agencies and the military during Humanitarian Assistance and Disaster Relief (HA/DR) events. Consequently, the NPS HFN Center has played an important role in recent disasters including the Southeast

2

Asia tsunami (2004), Hurricane Katrina (2005), USNS Comfort & USNS Mercy Partnership for the Americas and Pacific Partnership (2004), respectively, and the Haiti Earthquake (2010).

It is difficult to talk about emergency responses without considering the role that social and cultural aspects play into that response; most communities that respond to disasters are comprised of a close knit group of individuals who work together very well. The problem is when large disasters occur. Coordination across the different communities is not always that great. Each community will have a set of technological solutions that it prefers to use and each will have a specific language that it understands. California is no different, and the HFN model can help in bringing all the players to a common communications infrastructure regardless of location.

> The delivery of wildland fire protection services in California relies on an integrated, multi-agency effort to maximize the use of firefighting resources. This integration is essential to avoid duplication of firefighting resources and to allow the closest available resource to respond to a fire, regardless of jurisdiction. This integration is authorized by statute and guided by interagency agreements under which the state provides services to local and/or federal agencies, and vice versa. (State of California, 2010)

In most cases, a lack of one collaborative environment exists that enables the emergency responders to maintain a common operation picture (COP), or the ability to communicate and coordinate resources efficiently. While the HFN is not in itself a collaborative environment, it allows the players a way to access a collaborative environment, which is usually hosted by one of the organizations responding to the disaster and accessed via the Internet.

> The emergency response community recognizes that no single technological solution can address all emergency communications challenges or meet the needs of all agencies. The proprietary nature of many communications technologies creates an ongoing challenge to system connectivity and establishing interoperability among them. The presence of wireless data networks, Internet Protocol (IP)-based mobile communications devices, and location-based commercial services, however, are creating potential

3

opportunities to enhance command and control and situational awareness. Accelerating the development of standards for existing and emerging technologies can address these technology challenges, and therefore improve communications during response operations for both routine and significant events. (Chertoff, 2008)

1.   Katrina

In the report by the Government Accountability Office (GAO) regarding preliminary observations about Hurricane Katrina (U S Government Accountability Office, 2006), the report identifies the breakdown in emergency communications as one of the vital areas that caused wide dissatisfaction and contributed to the responding agencies being overwhelmed. During a disaster, enough resources may be available but without adequate communications, the response can be chaotic and will have the same negative effect as in Hurricanes Katrina and/or Rita. Widespread dissatisfaction with the response was attributed in large part due to the significant breakdown in emergency communications and the consequences of the breakdown that made coordination of vital supplies and equipment very difficult.

The GAO report points to the following three key themes that underpin the challenges encountered in response to these two disasters: (1) clear and decisive leadership, (2) strong advance planning, training and exercise programs, and (3) capabilities for catastrophic event.

The key element in all three is the ability to coordinate across a wide range of agencies that respond to any disaster. Clearly, all reports point to the fact that the infrastructure was not available to support this huge demand for the ability to coordinate across all agencies and players responding to the disaster. HFNs can fulfill these requirements in the early days of any disaster. They may not have the capacity to include all necessary solutions but they provide a framework in which the initial responders can build on and provide better response.

In the GAO report about Hurricane Katrina, the authors identify the lack of communications as a key factor that contributed to the poor response. Although the military has the capacity to provide a mobile command center, it was not in the area at the time the storm hit and could not be delivered on time (Walker, 2006). HFN concepts require very little resources, both in equipment and personnel, which makes it easy to deploy at a moment's notice.

Another critical point of the GAO report is the inability to establish a fully staffed office to respond to the disaster; in this case, it took 10–12 days. HFN can vastly improve this time by establishing communities of interest or working groups in advance. The advent of the World Wide Web (WWW) and all the applications created to collaborate over that medium makes it possible for experts to collaborate and help plan a response without having to be physically located in the disaster area. A pre-established community of interest composed of experts from different fields can be available at a moment's notice and help to plan the response. Anyone with access to the Internet can act as the eyes and ears for the experts. This capability was demonstrated in the recent X24 Exercise of February 2012 conducted by San Diego State University in which military and civilian agencies collaborated over the Internet to respond to a disaster scenario in Mexico. The demonstration had 1,308 participants representing 43 countries (San Diego State University, 2012).

The enabling factor to collaborate was access to the Internet, which allowed the experts and responders access to information in many different forms, video, voice and text. During X24, the communication infrastructure remained intact that allowed all the players continued access to vital information. However, this situation does not always occur. If communication infrastructure fails, a need for an HFN kind of solution will exist in which a team can deploy quickly to serve to establish that link with the rest of the world.

2. Mission of Military in Humanitarian Assistance and Disaster Relief

The most recent strategic guidance recognizes that to be efficient in achieving the strategic goals of this nation, a greater collaboration must exist between the military, civilian agencies and international partners.

> The global security environment presents an increasingly complex set of challenges and opportunities to which all elements of U.S. national power must be applied. (DoD, 2012)

This situation is not something new; the military has played an important role in every major disaster, from 9/11 to the Japan Tsunami of 2011. Its unique capabilities and vast resources make the military an important player to respond to natural or manmade disasters. In the past decade, DoD has issued a number of instructions and guidance to enable better collaboration with civilian partners. As it relates to this study, DoD issued a specific instruction for Information and Communications Technology (ICT) Capabilities for Support Humanitarian Assistance and Disaster Relief (DoD, 2009). This guidance recognizes that greater flexibility needs to be exercised by the military, and includes it as part of the DoD mission, which is the capability to provide ICT support to non-DoD partners during HA/DR operations.

The similarities of the needs of state and local agencies during a disaster are striking and the methods and procedures used to maintain and improve the Command and Control (C2) environment are also similar. It is also clear that one solution does not fit every problem or work under all environmental conditions. This study gives a foundation to the research of possible solutions that enable state and local agencies a better C2 and collaborative environment in which all resources can be used effectively, and thus, ensure better response.

In this study, the plan is to focus on the physical systems, players and interaction practices with an emphasis on the physical systems interoperability using available resources. Of course, many other issues with both the players and interaction practices do exist, but the purpose of the research will be twofold.

First, the focus is on the potential organizational benefits of using HFN as a standard business practice for the ERC. The second goal is to concentrate on identifying the best practices to implement the HFN concept, which includes the technological solutions and organization components necessary to provide a sustainable system for the ERC.

D.   SELF-ORGANIZATION

Self-organization is the process by which a structure or pattern appears in a system without a central authority or external element imposing it through planning. This globally coherent pattern appears from the local interaction of the elements that comprise the system. Thus, the organization is achieved in a way that is parallel (all the elements act at the same time) and distributed (no element is a central coordinator) (Self-organization, 2011).

The increased use of ICT is affecting the way information is consumed and used. Increasingly, expectations are that the information be consistently available with little regard for how the ICT systems maintain that environment.

For self-organization to occur, the first thing that needs to happen is the ability to build connections between the different members. HFN is the concept that provides that capability and introduces the missing link during certain situations. That capability has been proven to be the link that creates resiliency by providing an extra node to connect to the outer layers of the organization (fireman fighting a wild fire). As Barabasi suggests, this occurrence can be the enabler to many more capabilities or possibilities. "The construction and structure of graphs or networks is the key topology, affecting only a few of the nodes or links, can open up hidden doors, allowing for possibilities to emerge" (Barabasi, 2002).

The ability to maintain control is very important for emergency responders, which is very difficult in situations when the last link is missing. Although this community relies on a set of well-established patterns, it also depends on its capability to adapt as necessary to changes in the environment. HFN provides

7

one more opportunity to maintain control, even if the patterns are non-existent, and having the ability to communicate provides the means to "correct its mistakes, regulate itself, and organize itself" (Capra, 1996).

Considering prior research in the establishment of HFNs, one key requirement emerges to enable the collaboration among the many players who use the network, which is the need for a reliable network that has consistency in many different environments and can self-heal after links are broken.

E.   BENEFITS OF THE STUDY

Potential benefits from this research include enhanced response capabilities and potential costs savings to the local community as a direct result of enhanced response. The ability to coordinate resources among all agencies responding to a disaster will result in additional costs savings by eliminating duplication of effort and faster response. In wildfires, faster response generates savings produced by the ability to contain the fire when it is manageable. In an environment in which resources are limited, early response and better coordination of available resources is necessary. Even with the advances in technology, areas exist in which the communications infrastructure is limited and coordination of resources therefore is limited. The HFN concept bridges that gap by establishing communication networks under most environmental conditions.

In addition, this concept can be the model for other emergency response communities across the nation, as well as other agencies involved in disaster recovery/response.

F.   HASTILY FORMED NETWORKS

The ability to form multi-organizational networks rapidly is crucial to humanitarian aid, disaster relief, and large urgent projects. Designing and implementing the network's conversation space is the central challenge. (Denning, 2006)

HFNs played an important role during recent disasters that continue to be one of the most reliable means of communication for the responders. The NPS

HFN teams deployed to recent disasters provided the "conversation space" that Dr. Denning defines in his HFN paper. This space was a combination of technologies to pass the information to the places it needed to be and enabled people with the sets of skills to set up and maintain the HFN networks until the normal commercial networks became available again.

Briefly, the HFN concept includes a set of Fly Away Kits (FLAK) that includes communications, power, life-sustaining and Visualization equipment. To be considered a FLAK, the kits have to be limited in size and weight so that they can be checked in as airline luggage. Thus, the weight must be less than 100 lbs. and limited to the size of a typical check-in luggage size. The total HFN complement includes all elements necessary to be self-sustained for short periods of time, and more importantly, to provide the capability to establish communications in a short period of time. This component may be the first real connection with the outside world or it may be complementary to other communications resources already in place. Chapter II provides a detail description of each FLAK.

G. DEFINITIONS

Application	The special use or purpose for which something is used. A technology may have numerous applications never considered by its inventors.
BGAN	Broadband Global Area Network terminal, which is a satellite earth terminal owned and operated by the company Inmarsat.
Cloud Computing	A model of computer use in which services stored on the Internet are provided to users on a temporary basis.
Command and Control	The means by which a commander recognizes what needs to be done and sees to it that appropriate actions are taken.
Conversation space	Is (1) a medium of communication among (2) a set of players (3) who have agreed on a set of interaction rules. (Denning, 2006)

Database	A comprehensive collection of related data organized for convenient access, generally in a computer.
Data Transfer	Copying or moving data from one place to another, typically via some kind of network.
End User	The ultimate user for whom a machine, as a computer, or product, as a computer program, is designed.
Evolution	Any process of formation or growth.
First Responder	A certified, often volunteer, emergency, medical, or law enforcement officer who is the first to arrive at an accident or disaster scene.
Footprint	The shape and size of the area something occupies: enlarging the footprint of the building, a computer with a small footprint.
Gateway	Portal to the Internet
HA/DR	Humanitarian Assistance/Disaster Relief mission to deploy to a disaster area.
Hardware	The mechanical equipment necessary for conducting an activity, usually distinguished from the theory and design that make the activity possible.
Hastily Formed Network	The ability to form multi-organizational networks rapidly that are crucial to humanitarian aid, disaster relief, and large urgent projects.
Hotspot	A hotspot is a site that offers Internet access over a wireless local area network using a router connected to a link to an Internet service provider. Hotspots typically use Wi-Fi technology.
Meals Ready to Eat	A self-contained, individual field ration in lightweight packaging bought by the United States military for its service members for use in combat or other field conditions where organized food facilities are not available.
Reliability	In general, reliability (systemic def.) is the ability of a person or system to perform and maintain its functions in routine circumstances, as well as hostile or unexpected circumstances. In this case, reliability is directly related to the system ability to self-heal after it has failed and in the ability to maintain connectivity consistently with all the nodes.

| Small Form Factor | Limit the weight and size to the equivalent of a check-in baggage so that it can be taken via commercial air as part of the luggage. |

H. METHODOLOGY

The methodologies used to meet the requirements of this thesis consist of the following.

- Review of articles, after action reports, and statistics from the major disasters in the last 10 years with the purpose of identifying the best practices and lessons learned as they relate to the communications capabilities during the early stages of a disaster.

- Review of past theses on related topics that can contribute to the body of knowledge of HFN's and how these concepts can enhance the local ERC.

- Based on the previous research and the work done at the HFN Center at NPS, provide a discussion of HFN basic components, capabilities and challenges.

- Provide a detailed account of the NPS Independently Powered Command/Control/Communication Program (IPC3) field demonstration of HFN concepts with the local ERC.

- Participate in various NPS HFN Center field demonstrations and field exercises.

I. THESIS STRUCTURE

This thesis is organized into the following chapters.

Chapter I provides an introduction and overview of this thesis.

Chapter II gives a synopsis of HFN. This chapter provides a basic overview of the definition of HFN, its background, and components as defined by the previous research and the NPS HFN research group.

Chapter III describes the HFN puzzle to include the architecture, people and technologies. This chapter provides a description of all nine elements of the HFN puzzle that serves as the foundation for the NPS HFN research group.

Chapter IV provides an overview of the demonstration of HFN concepts and technologies at Big Sur, CA as part of the IPC3 project in collaboration with

the local emergency response community. This chapter describes all major components including hardware and software, and presents an overview of the location time and scenarios used to demonstrate the HFN model.

Chapter V provides the results of the demonstration broken down by the major components and summarizes the results of the demonstration.

Chapter VI concludes this thesis.

II. HASTILY FORMED NETWORKS

A. BACKGROUND

The past decade has had an unprecedented number of disasters that required the quick formation of networks to coordinate the response and to manage all resources. Some of the major disasters included the Indian Ocean tsunami of December 2004, Hurricane Katrina in August 2005, the magnitude 7.6 earthquake of Pakistan in October 2005, and the magnitude 7.0 earthquake of Haiti of January 2010. In each of these disasters, the HFN research team from NPS played an important role both as a research institution and as a partner with other agencies to assist in the rapid response. The HFN mission was to establish as its namesake calls it, a hastily formed network capable of supporting a large HA/DR response community.

Each time, the severity of the disasters made clear that the quality of the response depended largely on the quality of the network established after the disaster to provide relief. (Denning, 2006) With this in mind, NPS continues its research during each disaster, and in 2004, coined the term HFN. The research has shown that the need to establish a network capable of including multiple organizations with no common authority, with very different cultures and internal organization was key to enabling quick response. The kinds of events requiring HA/DR response necessitate different sets of skills from the response community depending on the scenario. Some events may be well-rehearsed scenarios in which the response community has vast experience and have a pre-determined set of procedures to follow that enable an efficient response. Other events may be completely new in which most of the factors are unknown. Dr. Denning provides a table that better explains these categories. See Table 1.

Much of the research has focused on the response to large disasters in which the community that responds is comprised of a large number of agencies from different parts of the world. The recent fires in California and specifically, the

Reliz Fire Incident of 2011 drove home the point that the local emergency responders can enhance their response if they have the capabilities of HFN (Klemek, 2011). These fires fall under the category of known unknown (KU) but the shortfall is in the technological tools necessary to establish the communications network to support the HFN concept.

Category	Characteristics	Examples
K: Known	Know what to do Use existing network structures May chose not to respond	Fast response team for time-critical business problem or opportunity
KU: Known Unknown	Know what to do Don't know time or place Responding network structure known	Local fire, small earthquake, civil unrest, military campaigns
UU: Unknown Unknown	Don't know what to do Don't know time or place Responding network structure unknown	9/11 attack, other terrorist attacks, large earthquake, major natural disasters (Note: KU events can become UU events when scaled up to large areas or populations)

Table 1.   Kinds of Events Requiring Response from Hastily Formed Networks

B.   DEFINITION

The HFN concept is a set of technological solutions and personnel that enables the establishment of a network in an austere environment to support communications and collaboration for a diverse group. Dr. Denning identified the five components of HFN as follows.

> An HFN has five elements: it is (1) a network of people established rapidly (2) from different communities, (3) working together in a shared conversation space (4) in which they plan, commit to, and execute actions, (5) to fulfill a large, urgent mission.

As explained above, the HFN is much more than a set of technological solutions. HFN includes personnel with the skills necessary to set up and

maintain the communications infrastructure and skills necessary to interact with people and agencies working towards the same goal but with no apparent leader. Together, the people skills and technology comprise the conversation space necessary to establish and maintain the communications environment in which all players can access and coordinate resources as needed.

The conversation space was defined by Dr. Denning as (1) a medium of communication among (2) a set of players (3) who have agreed on a set of interaction rules. Table 2 shows the components of the conversation space (Denning, 2006).

Category	Characteristics	Examples
Physical Systems	Media and mechanisms by which people communicate, share information, and allocate resources	Telephone, power, meeting places, supplies, distribution systems.
Players	Players included and their roles, core competencies, and authorities	Citizens, fire department, police department, highways department, federal emergency management agency
Interaction practices	Rules of the "game" followed by players to organize their cooperation and achieve their outcomes	Situational awareness, sharing information, planning, reaching decisions, coordination unified command and control, authority, public relations. (Note: environment has no common authorities no hierarchy, many autonomous agents, decentralized communications)

Table 2.   Components of Conversation Space

While the conversation space may seem trivial, in reality, it is a complex environment in which the technology alone is not enough to enable communication and collaboration among the players. The complexity is due to the varied background of the players and their culture. Each organization is

biased towards whom to share information with, and add to that space, the difficulties of a stressful situation. The complexity increases and leads to difficulties in establishing an ideal conversation space (Pfeifer, 2005).

HFNs are more than a technological solution; they are a set of conditions that enable collaboration among a diverse group. Ideally, every player in a disaster would be able to communicate and work together with any other member of the response team. This circumstance is only possible when the players have an established relationship or have a common purpose, which is hardly the case in most situations. Since 2005, the HFN team at NPS under the leadership of Brian Steckler has been able to increase the effectiveness of the HFN concept by establishing relationships among the many players who respond to a disaster. The efforts taken by the HFN team at NPS enhance the response by bringing together the players and familiarizing everyone with the cultural or organizational differences and the technologies used.

III.   THE HFN PUZZLE

A.   BACKGROUND

The capabilities desired for an HFN model require many components. The simplicity of the model relies on the use of Commercial-Off-The-Shelf (COTS) technologies, but it also includes many other aspects that comprise the model, including the sets of skills necessary to set up and maintain the network. The NPS HFN research group identified nine pieces of the HFN puzzle: (1) power, (2) applications and communications, (3) environmental needs support, (4) WiMAX, (5) SATCOM/Internet, (6) Wi-Fi mesh, (7) voice communications technologies, (8) NOC security and system management, and (9) personnel skills sets (Steckler, 2005).

Figure 1.   The Nine Element HFN Puzzle

To help in understanding the complexity of the model, this section provides an overview of all nine elements. The following section includes a more detailed explanation of specific components. It is important to remember that this

is a flexible model and that each configuration depends on the conditions on the ground, the experience of the users, and the resources available.

B. THE NINE ELEMENTS OF HFN

1. Power

The challenge is the initial austere environment in which no infrastructure may be available to sustain effective first responder activity in an HA/DR scenario. Power is essential since without it, none of the IT components of an HFN will operate. A network must have a reliable source of power to sustain normal operations in these environments.

The primary components of the power equipment are generators and batteries. Generators are typically gasoline powered generators, fuel cells and solar or wind generators. The advantage of fossil fuel generators is the high power output but the disadvantage is the need for fuel. In most cases, the ideal scenario is to be self-sufficient; those who bring generators must also bring the fuel or find a reliable source for it.

Fuel cells have some advantages, as they require very little fuel, but at the same time, do not produce as much power as a gas or diesel generator. The benefit of solar (solar panels) or wind (wind turbines) generators is that it is not necessary to find fuel. Before deciding on what sources of power to use, specific considerations need to be made based on the performance characteristics of each option. While gas or diesel generators have very good performance characteristics, they can be an added burden in areas were fuel is not readily available. On the other hand, solar or wind generators do not depend on the availability of fuel; instead, they depend on the specific solar radiation profile and or wind patterns of the specific location. In certain areas, the potential to generate from wind or sun is so limited that it does not make sense to consider this option.

Batteries are an important component for all systems in that they provide a medium to store the energy generated by any method and can be the whole

source of power when no fuel is available. However, they are heavy and must comply with strict regulations to be transported via air.

Solar Stik™ is an example of a system that combines solar, wind and fuel cell technologies to generate electricity under any condition.

2.   Applications and Communications

As the use of media devices from smart phones, tablets or laptops becomes ubiquitous across the globe, an expectation exists among the population that access to the Internet will be available at all times. Additionally, more and more business practices and interactions between people and agencies happen over such mediums. The file transfer abilities, File Transfer Protocol (FTP), texting Short Message Service (SMS), and other applications to collaborate require access to the Internet.

The list of available technologies or applications that enable collaboration continues to grow to include Voice over IP applications, such as Skype, or Google chat, shared desktop applications, such as Microsoft SharePoint and Google docs, and others. The increased use of mobile devices and the proliferation of mobile apps is another example of how more and more people generate and consume information.

These developments present a new opportunity for organizations that respond to manmade or natural disasters. The primary challenge in responding to disasters is communication. Reasons include the many differences among the responders in the type of technology used for communication (Manoj & Hubenko Baker, 2007). The ubiquitous use of smart phones opens up a new conversation space in the cloud, in which services are stored in the Internet. Research is being done in the field of mobile apps to measure the potential benefits of using crowd sourcing to measure the impact of any disaster. In the aftermath of the East Japan Earthquake of March 2011, the traditional methods established to provide communications to responders was not available but reports from social media (Twitter, Facebook and Mixi) breached the gap. People with social media

accounts served as the eyes and ears providing updated information about the extent and severity of the disaster (Arifumi , Mixumoto, & Okumura, 2011).

The common thread in the opportunities that mobile devices bring to the table for better disaster response is access to the Internet, and the concept of HFN provides that access. While HFNs may be limited in the number of users that they can support, it is essential because the Internet may be the only source of information, and in many cases, can be the only reliable conversation space for the responders.

3. Environmental Needs Support

Without food, water and shelter the people setting up the HFN will not be able to stay healthy and to take on the challenges that a disaster brings. During natural or manmade disasters, the resources available are limited. In many cases, no resources exist and responders need to be self-sufficient for a reasonable period of time until supply lines and resources become available. The HFN team is no different. Advanced planning must be part of the process to ensure resources for the environmental needs are available so that a team can deploy at a moment's notice. For this purpose, the NPS HFN Center developed the Maslow[1] FLAK, which includes all necessary equipment and supplies to sustain healthy first-responders activity during a disaster. The kit includes water/air testing equipment, water filters and purifiers, cooking gear, meals ready to eat (MREs) shelter equipment, and tracking or navigation equipment.

4. WiMAX: 802.16 (OFDM) and Related Technologies

WiMAX (Worldwide Interoperability for Microwave Access) is the Institute of Electrical and Electronics Engineers (IEEE) 802.16 standards-based wireless technology that targets providing wireless data communication over longer distances, and is recognized as a last mile solution, connecting homes and office business communications. This wireless broadband solution offers a rich set of

---

[1] Maslow's hierarchy of needs in which Maslow identifies the basic physiological needs for human survival (Air, water, food and shelter)

features in terms of deployment options and potential service offerings. The two primary ways in which this technology is used is on a fixed (point-to-point) and mobile configuration. The fixed wireless broadband can be thought of as an alternative to DSL or cable modem. Mobile broadband has the additional functionalities of portability, nomadicity, and mobility. This latest development has the potential of enabling use of mobile broadband applications (Andrews, 2007).

Important features of WiMAX include the OFMD-based physical layer, a scheme that offers good resistance to multipath, and allows WiMAX to operate in near-line-of-sight (NLOS) conditions. It is also capable of supporting very high peak data rates, which are as high as 74Mbps when operating using a 20MHz wide section of the spectrum. Additionally, the point-to-point links can be up to 50 miles apart.

WiMAX works well in a HA/DR environment as it is inexpensive, easy to deploy, very reliable, and readily available on the market. Simple systems are available that consist of a radio, antennas, and power source on each end. Many have radios and antennas integrated and mount both at high point in the area and the Internet connection inside, usually called "outdoor units" (ODU) and "indoor units" (IDU) respectively. In disaster zones, the WiMAX antennas must be positioned as high as possible (on hilltops, tops of tall buildings, surviving water or cellular towers, etc.) as WiMAX is a "line of sight" technology (Steckler, 2005).

5. SATCOM/Internet

The backbone of the HFN model is access to the Internet. To access the Internet in an austere environment, the HFN model uses two different technologies, very-small-aperture-terminals (VSAT) and or Broadband Global Area Network (BGAN) units. Each has certain advantages and disadvantages. While BGAN units are typically small and are easily carried on a backpack, they provide limited bandwidth. On the other hand, VSAT units provide higher broadband capability but are typically large, which makes it hard to deploy quickly. The use of BGAN meets the goal of keeping size and weight to a

minimum while providing rapidly deployable and easy to set technology. BGAN is usually enough to support a small team but considerations need to be made if the support is needed for a large group, and for longer period of time in which case, the use of VSAT would be more desirable.

To establish an Internet connection, both units require a clear line of sight to the satellite and access to power. Again, the advantage on BGAN units is that some units already have internal batteries and can operate for hours. Other considerations include the capacity of the units to establish a Wi-Fi cloud, which makes obtaining access to the Internet even easier.

6.   Wi-Fi Mesh (WLAN)

Just as WiMAX, Wi-Fi (also known as 802.11) uses radio waves to communicate between Wi-Fi enabled devices. The basic process performed by these devices is to take data in the form of a digital signal (binary code) then convert it to an analog signal. This signal is then transmitted over the air and the receiver then convers it back to a digital signal. The evolution of these devices is also improving the speed at which data can be transmitted. 802.11n is the newest standard and has reportedly achieved speeds as high as 140 Mbps. The previous version and the most commonly used was the 802.11g that achieved speeds of 54Mbps but had some problems in sustaining that speed due to network congestion. The real-world speed achieved was approximately 24 Mbps (Marshall & Wilson, 2001).

Any device with a Wi-Fi adapter can use a router to connect to the Internet. The connection is convenient, invisible and reliable. The only disadvantages are that one router can support only a limited number of users, and that there is one point of failure, the router. The NPS HFN Center uses this technology to create wireless clouds in large areas (up to several square miles or more) with a few strategically positioned wireless access points (APs).

Wi-Fi is the last mile link for wireless users, and specifically, for emergency responders, provides access to the applications necessary to

maintain a Common Operational Picture (COP) that can include communications applications like email, chat, and Voice over IP (VoIP), etc. Additionally, the development of new technologies has made possible the creation of self-healing/forming networks with Wi-Fi devices. One example is the way in which Rajant and Persistent Systems are using Wi-Fi technologies to create wireless mesh networks.

7. Voice Communications Technologies

Voice communications include land mobile radio (LMR) cell phones and Internet-based or broadband-based technologies like Voice over IP (VoIP) or Skype. With the exception of LMR, all other technologies have the Internet as the common denominator that enables integration of as diverse a group of users as possible. The NPS HFN Center research continues to work to make voice communications an integral part of the HFN model. All recent NPS HFN Center demonstrations and field experiments have always included the use of at least one voice communication technology based on a broadband solution, such as Skype.

The challenges of LMR systems are the number of varying, often incompatible systems in use by the members of the emergency response community. As a result, these systems struggle to communicate across jurisdictions and agency lines. The HFN model solves this challenge by making the Internet the common platform in which any user with access to the Internet can communicate across jurisdictions and agencies.

8. Network Operating Center (NOC), Security and System Management

Each organization has specific structures that enable it to maintain control over its resources during a disaster. The traditional method is a mobile operation center that acts as the central nervous system of the organization to process information and to manage resources. Unlike traditional NOCs, the NPS HFN model considers the need for deployment at a moment's notice and over long

distances often via commercial air, which leads to the development of specific requirements to enable the establishment of a mobile NOC in an austere environment. The following considerations need to be part of the planning phase: availability of facilities, security issues, physical access to resources, and logistics requirements.

These considerations require that the HFN team plan the network setup so that an adequate balance exists between security requirements and basic communication needs. Security requirements include both virtual and physical and the balancing act will have to ensure that essential communication channels stay protected, and at the same time, provide access to the general population so that essential information is distributed and collected to enable better response.

9.   Personnel Skills Sets

Part 9 of the HFN puzzle is the personnel skills sets. Although with the advent of the Internet, expertise in the ERC is available virtually all the time via the extended network of responders, a need still exists for basic skills sets to set up, operate and maintain an HFN. These skills can be divided into two categories, technical and people or social skills, and when combined, they facilitate the interaction among people, processes, organizations, and technology of an HFN. Technical skills require the knowledge and proficiency to set up, maintain, and troubleshoot all the different components of the HFN, including power, communications and life-sustaining equipment. The same is true for the soft or people skills. The diverse community of responders requires that individuals have the skills necessary to work within the community and the ability to understand it. Once a network is established and access to the Internet is available, these individuals have access to an extended network of experts including individuals, businesses, and government (civil and military), and research centers, and as such, those people skills come in handy.

C. NETWORK ARCHITECTURE

1. Introduction

To understand how the HFN concept can help the ERC during disasters or emergencies, it is essential to understand the requirements of its mission. The area in which HFN can play a significant role is the basic need for information with specific time and place requirements. The command and control center needs all relevant information across a wide operating area. This may be all information about fires spread over two or more counties, a power outage in one or more cities, or other emergencies that necessitate the need for coordination among a number of emergency responders and across a large area. In contrast, the individual firefighter will need only what can be used in a very small focus area. It is necessary to know the particulars about the local problem; for example, for a fire, the information relevant would be location, spreading direction and speed, and the local community's population in need. The HFN architecture meets these requirements with a basic configuration. See Figure 2.
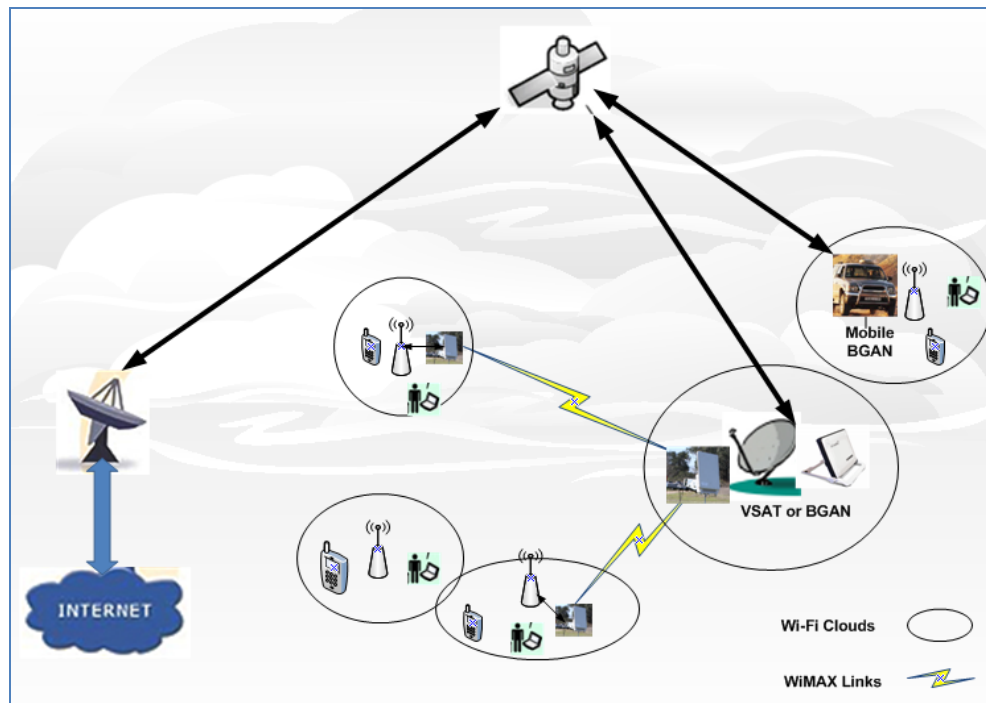
Figure 2.   HFN Architecture

2.   Satellite Gateways

In an austere environment, the options for access to the outside world are limited to a satellite connection. Satellite service provides access virtually worldwide. The service has some limitation depending on the location; for example, access in the poles is limited but coverage on most of the earth's surface is available. The disadvantage is the cost of the service as compared with the standard cellular or wired connections, and latency on the signal due to the distances the signal has to travel. Another limitation is that the satellite unit will need a line of sight to the satellite; even foliage can be an obstruction and can cause limited or no connectivity. The last disadvantage is the limited amount of data transferred via a satellite connection. This limitation is due to the link budget of the system, which considers among other things, the size of the antenna, the power of the receiver and transmitter, and the distance to the satellite.

The way a satellite sends the information down to Earth is similar to the way a flashlight illuminates a dark area. The closer the area is to the bulb, the better light it receives, and also by narrowing the beam of light, a distant area can be illuminated better. Satellites use similar methods to provide coverage for an area. A wide beam provides coverage for a large area but has low power while a narrow beam provide coverage for smaller areas with a more powerful signal.

Satellite communications have a designated set of radio frequencies. The frequencies used have ranges from 3 GHz to 31 GHz broken down into four bands designated by the letters C band, L band, Ku band, and Ka band. C band has frequencies from 3 to 7 GHz, and can provide a large coverage area with low power and with minimal effect of rainfall. Ku band includes frequencies from 10 to 18 GHz, and provides medium area coverage with medium power and moderate effect of rainfall. Ka Band includes frequencies from 18 to 31 GHz, and provides small area coverage with high power but it has severe effect from rainfall.

There are two types of services to establish a satellite link; Broadband Global Area Network (BGAN) and Very-Small-Aperture Terminal (VSAT).the basic differences between these two services is provided in table 3. In both cases, the signals transmitted over the air are analog signals and need to be converted to digital signals so that computers can read the information. Built in modulators-demodulators (modems) make this conversion. When a signal is sent, the modulator converts the digital signal to analog signal and when a signal is received, the signal is then converted from analog to digital by the demodulator.

a. VSATs

The first data links to satellites required large parabolic antennas (dishes) measuring five meters in diameter and complex electronic equipment that made them very costly; therefore, the use of these devices was limited to organizations with deep pockets. With technological advances in the satellite industry, it is possible now to use smaller and cheaper dishes. These smaller antennas known as VSATs are now available from a number of service providers and provide an alternative to those who have no access to the WWW via a wired connection.

A VSAT can provide an Internet connection with uplink speeds of up to 2 Mbps and downlink speed of 5 Mbps. The sizes vary but most are approximately one to three meters in diameter. Service providers developed different configurations to meet specific needs. Vehicle and trailer mounted VSATs come with power sources and electronics to operate for longer periods and provide broadband connectivity to larger areas. VSATs are also configured as a FLAK but they do not include a power source.

b. BGAN

Broadband Global Area Network (BGAN) technology was created in 2006 and was designed to be transported by a single person and able to connect to a satellite within minutes. It is an ideal solution for a first response

team because of its lightweight, speed, and ease of use. Some BGAN units are ruggedized and some models come with the capability to broadcast a Wi-Fi signal with similar or better broadcasting capability than a standard home modem. An additional feature of the BGAN is its ability to designate the speed of the connection when first synchronized to the satellite, which can be seen as both an advantage and a disadvantage. The user does not necessarily obtain the best speed all the time, but the user will know the exact speed of the BGAN connection.

Just as with a VSAT, BGAN units rely heavily upon Line of Sight (LOS) to the satellite, and when deployed in metropolitan areas with big buildings or in mountainous areas with large mountains or large trees, it can be difficult to establish and maintain connections. Since the BGAN is limited in bandwidth (256 ~ 400 kbps), it is not the most ideal gateway for reach-back capabilities using virtual technology.

BGAN	VSAT
Operates in L-band	Operates in Ku-band
Smaller, less expensive terminals	Larger, more expensive terminals
1/2 MB bandwidth max	1-2 MB bandwidth max
Highly portable	Man-portable
Communications "on the move" through small terminals	COTM requires larger terminals
Operates in rain, dust storms, wind	More sensitive to environmental conditions
Higher per MB/per minute costs	Lower per MB costs

Table 3.   Differentiation BGAN vs. VSAT (From: Steckler, 2012)

IV.   DEMONSTRATION EXPERIMENTATION

A.   BACKGROUND

The design of demonstration experiments has the purpose of showing how specific issues, approaches and/or federations of systems provide a utility for a targeted group (Alberts & Hayes, 2009). In this theses we use, the field demonstration/experimentation that took place in Big Sur CA, the site of some of the recent wild fires that are part of the jurisdiction for the Monterey ERC. The specific purpose this time was to demonstrate how the HFN concept would increase the capacity of the ERC to manage the resources available and to respond better to the fires.

This IPC3 demonstration focused on introducing the concepts of HFN to a new community and to demonstrate how these concepts and technologies can enable among other things better communication flow, better collaboration, and as a result, better self-organization by those who use it. The demonstration was conducted in two separate phases. Phase one was training, in which all the primary users or technical experts had an opportunity to learn and to see the technologies working. The second phase was a demonstration exercise with a larger group that included members of the ERC. In addition, members representing the different manufacturers from the technological solutions participated and provided equipment and expertise during the demonstration.

B.   LESSONS LEARNED FROM PREVIOUS EXPERIMENTS

Much of the previous research has shown that the emergency response community is continuing a trend to make better use of IT systems, from the initial 911 system of telephone communications developed in 1968 to an array of mobile and computer-aided networks of today (Horan & Schooley, 2007). Other demonstrations were conducted after the gap in communications was identified.

These demonstrations focused only on the capabilities to provide wireless communications reliably in areas in which the infrastructure was destroyed or when none existed (Scott & Charles, 2005).

The NPS HFN research group discovered that choosing the right Satcom for a HA/DR mission is the key to success and provides the following timeline as a guide for deployment.

- BGAN first in……then VSAT…..then cell networks up
- When you need small/light/fast/easy IP connectivity, there is no other choice than BGAN - for the price and capability
- When you need bandwidth, there is no other choice than VSAT
- When long term deployment expected, VSAT best option…or short term BGAN best option
- When resource constrained, flat VSAT fees favorable (From: Steckler, 2012)

Additionally, the aforementioned articles in Chapter One provide the basis for the need to develop a mature method to install reliably the IT infrastructure necessary to access all the planning and coordinating tools used by the emergency responders immediately after a disaster strikes disabling the existing IT infrastructure or when none is available.

C.   PERSONNEL/TEAM COMPOSITION

During this demonstration, one of the factors that was considered was the experience of each member. Part of the demonstration considers the ease of use capabilities of the technologies demonstrated and the ability of members of the emergency response community with varied experiences to operate it. Some members have vast experience with a varied number of communications technologies, and as such for them, learning to operate new communications equipment may easy. Others may have very limited experience that may affect their ability to learn new technologies in a different way. In both cases, no guarantee exists that one group will do better than the other. Thus, the

demonstration attempted to include a number of individuals who represented the entire population to ensure that the lessons learned can be applied to all.

A lead for each major area (Wi-Fi, SATCOM, WiMAX and alternate power) was assigned to direct the setup and demonstration for those technologies. The leads also served as the primary observers for those areas. As this was a demonstration, the focus was on the interaction between users and technology. The technology was previously tested and its capabilities proven during preliminary training with a limited number of users.

1.   Technical Experts

The technical experts included the research group from the HFN group at NPS and the communications experts from the emergency response community and representatives from the manufacturers. The HFN group included the students conducting research. As this group has experimented with the technology in different locations, and after the manufacturer's representatives, are the most experienced group. The emergency response experts have had some training prior to the demonstration and assisted in training the rest of the users. Prior to the demonstration, representatives from the manufacturers provided advice and training to the students and teachers in the HFN research group. In addition, they acted as observers to evaluate how well their systems perform under these conditions, and stood by to assist in the event that the HFN experts encountered difficulties and were unable to resolve any issues.

2.   Users

The group of users included members from all levels of the emergency response community, from top leadership to volunteers, and members of the NPS HFN research group.

3.   Observers

No group was dedicated specifically to observe due to the large number of activities and limited number of personnel. Instead, all participants were required

to act as observers and used form Incident Command System (ICS) 214 to track every activity and to document all observations and lessons learned during the demonstration.

D.   SCALE AND TRANSITION TRENDS FOR THE DEMONSTRATION

This demonstration was only the first in what will be a series of demonstrations to evaluate the different technologies and to evaluate the interactions between people and technology. Already, the community of emergency responders has expressed interest in conducting more field exercises to both train and to learn how these technologies can improve their ability to improve their response to emergencies. A single demonstration or exercise has many limitations, and therefore, many risks are associated with drawing conclusions from a single exercise. The risks include (1) moving ahead without sufficient evidence and understanding, (2) prematurely settling on an approach, (3) confining explorations to the industrial-information age border, (4) progressing by trial and error as opposed to being guided by theory, and (5) failing to capitalize on the creativity present in the force (Alberts & Hayes, 2005).

A campaign of experimentation is the only way to avoid the risks associated with conducting only an initial demonstration or experiment to ensure an opportunity to discover the best available technological solution, and best business practices for the users considering a wide range of alternatives. The economic reality (limited resources) for the emergency response community prevents a full-scale campaign of experimentation in which all available technologies can be tested and evaluated in adverse environmental conditions. However, as a minimum, the demonstration should be conducted periodically as part of the training until the users gain enough proficiency with the different technological solutions to identify shortfalls and possible ways to improve it. Additionally, the organizational changes that new technology brings must be carefully documented and examined to ensure the benefits outweigh the risk of implementing it.

E. DEMONSTRATION ELEMENTS

Design variables can be divided in three categories: dependent, independent and intervening. Independent variables answer the question "What do I change?" Dependent variables answer the question, "What do I observe?" and intervening variables are those that cannot be controlled.

During the demonstration, the following variables were considered.

- Independent:
  - Sustained communications
  - Self-healing or ability to re-establish the network when a link is lost
- Dependent: Reliability
- Intervening: Terrain, weather, and user proficiency with the system

Since this was a demonstration, the observation needed to consider additional factors related to the operator's experience with communication technologies and the ease of use of the technology. The main purpose for observing these factors was to determine what kind of burden this system will place on the emergency response community. The benefits needed clearly to outweigh the burden of implementation. Therefore, it is also necessary to observe the differences between scenarios in which the technologies proposed are used vs. scenarios without them.

The Network Management Tool developed by Rajant (BC|Commander®) was used to monitor the connectivity of all users to a BreadCrumb® (BC) or connectivity between BCs. BC|Commander® is used for the administration of the BC network. Some of the options this tool can provide and that are helpful for the demonstration include the following.

- Topology map showing BC and Client device connections
- BC/Client device channel, frequency, MAC address, IP address, nickname assignment, signal and nose levels
- Channel and link speed of connections

1. Location

The three primary sites for the demonstration are (1) Andrew Molera State Park Campground (functioning as Incident Command Site and field overnight camping location for all hands), (2) Andrew Molera State Park Parking Lot (functioning as scenario first "hotspot"), and (3) Point Sur Navy Facility (functioning as the Remote Emergency Operation Center (EOC)).

Figure 3.   Demonstration Exercise Location, Big Sur CA.

2. Timeline

The timeline for the demonstration exercise included a three-day period that covers the three days spent in the field and did not cover the planning, and training phase. Table 4 provides the timeline of events. See appendix A.

3. Demonstration Scenario and Initial Plan Structure

The IPC3 exercise scenario was designed to mimic a real event experienced by the ERC in the same location. In the scenario, CalFire is called to respond to a fire in Big Sur. The location is near Andrew Molera State Park at which none of the standard communications infrastructure works. CalFire utilizes a satellite connection using BGAN and/or VSAT to gain access to the Internet and use the HFN concepts to establish a local network at the vicinity of the command and control center and extend the network to the remote locations as needed to respond to the disaster.

This network is the primary means of communication and command and control for the ERC. The HFN concept tied directly to the existing capabilities brought by the ERC and augments or extends their capabilities. It was also set independently and tied in with the ERC via web-enabled applications, primarily Skype.

As part of the scenario, the planners developed a list of injects that call for specific responses. Each inject is associated with specific technological aspects of the HFN model. Appendix B lists the objectives and the expected response to each.

F. HARDWARE/EQUIPMENT

The hardware or equipment available to implement an HFN is increasing, with the ubiquitous use of the WWW as the primary way to consume information; more companies are developing mobile devices and technologies that enable access to the Internet. The demonstration used only a limited amount of hardware/equipment to represent each of the technologies that compose the HFN model.

1. Salinas Fire Department Command Vehicle 5390

During the demonstration, the Monterey County ERC brought its new command vehicle. The Salinas Fire Department Command Vehicle (SLS

Command 5390) is a FEMA Type-1 command and communications vehicle located in the California Emergency Management Agency (CALEMA) Region 2. Salinas, CA. SLS Command 5390 employs numerous technologies in the areas of HD camera systems, forward looking infrared (FLIR), high-speed mesh networking, video streaming, satellite broadband, RF interoperability, large format printing/GIS, video conferencing, and integration with Monterey County 911 public safety answering point (PSAP) telephony.

SLS Command 5390 is an important component for any disaster. Therefore, it is important to demonstrate how the HFN model and its technologies augment its capabilities. During the demonstration, SLS Command 5390 was used as the command and control center and was the primary VSAT source.

2. WiFi Mesh (Wireless Local Area Network (WLAN))

WiFi (also known as 802.11) creates "wireless clouds" at Internet access speeds of 1-10 mbps or more in large areas (up to several square miles or more) with a number of strategically positioned wireless access points (WAPs). This same technology is used in airports, coffee shops, etc., for public access to the Internet wirelessly.

WiFi enables the following.

- Mobile operations for laptops, PDA, handheld VoIP phones, remote sensors for situational awareness, etc.
- Multiple WAPs to be integrated in an area, thereby increasing the footprint of the wireless cloud by using technology known as "wireless mesh"

Once a wireless mesh is established, all Internet applications can be used throughout the mesh as the client machine moves around an area. Mesh technology provides for seamless hand-off from WAP to WAP as the client machine roams.

a.   *Rajant BreadCrumb®*

Rajant Corporation's BC wireless network (an example of Wi-Fi mesh product) is mobile and can be set up within minutes in virtually any environment. When operated with satellite based Internet connectivity, BC devices enable Internet access and VoIP communications to large areas and many users. It offers unique traits in portability and non-line-of-site networking (NLOS) nodes that intelligently route and broadcast in standard 802.11 protocol (RAJANT, 2011).

The benefits of BCs technology include the following.

- True mobility with continuous network availability
- Simplicity—single switch operation, auto configuration and self-healing
- Load balancing capabilities
- Power options—depending on model, battery, AC and DC power options

During the IPC3 demonstration, the BC were used to provide Wi-Fi access for each area and also to provide a mesh network. Additionally, a vest was configured with a BC, power and IP camera to provide live video while in the area of coverage. This configuration enabled two objectives as it extents the mesh enabling access to other users within the area, and at the same time, enabled the capability to provide live video while on the move.

Figure 4.   Stationary and Mobile BreadCrumb® Configuration

Three Rajant meshed Wi-Fi units were used for the demonstration, the LX4, ME3 and JR. Table 6 shows the basic differences between these units. Full specifications can be found at http://www.rajant.com/.

Model #	Wireless	Power	Physical
JR	Radio: IEEE 802.11b/g, 2.4 GHz Frequency: 2.402–2.472 GHz Max transmit Power: 25 dBm ± 1 dB	Input V: 10.5–25 VDC Power: 3 W @ 24 VDC	Size: 186 mm x 38 mm x 35 mm Weight: 297g
ME3	Radio: IEEE 802.11b/g, 2.4 GHz or 900 MHz Frequency: 2.402–2.472 GHz or 902–928 MHz Max transmit Power: 2.4 GHz : 28 dBm ± 1 dB	Input V: 6–16 VDC Power: 8 W @ 12 VDC (Not charging) 17 W @ 12 VDC (charging)	Size: 176 mm x 95 mm x 48 mm Weight: 1020 g
LX4	Radio: Frequency: 2.402-2.472 GHz 5.735-5.835 GHz Max transmit Power: 28 dBm ± 1 dB, 28 dBm ± 1.5 dB	Input V: 24 — 48 VDC Power: 23 W @ 24 V (peak)	Size: 195 mm x 187 mm x 61 mm Weight: 2000 g ± 150 g

Table 4.   BreadCrumb® Basic Characteristics (From: RAJANT, 2011)

The Rajant developed InstaMesh®, a Linux based software for mission critical applications. InstaMesh® resides on each BC, allowing for hundreds of resilient mesh connections to other BC devices, even while they are moving. The network quickly adapts to the changes caused by the movement of a node. New resilient links are established in real-time keeping the network available, intact and secure (RAJANT, 2011).
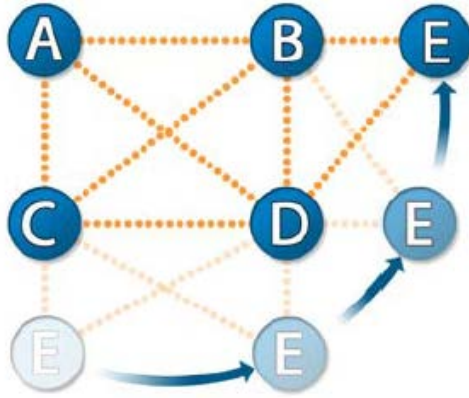
Figure 5.   BreadCrumb® Network Adaptation

BC|Commander® is a software package used for monitoring the status of BC Wireless Networks (BCWN), to configure the BC and to portray the network topology graphically. BC|Commander® typically runs on a laptop PC, but it can run on any PC that has access to the entire BC network. This tool provides a global view of the network with an easy-to-use interface (RAJANT, 2011). The features of the BC|Commander® include the following.

- Secure, encrypted link to each BC in the network
- Point-and-click BC configuration
- Real-time network topology view
- Wireless client display
- RF status display for all mesh and client links
- Ability to update BC firmware remotely (most models)
- Configuration of client link security up to WPA2-PSK
- Control of all other configurable BC features including radio settings, mesh encryption and authentication, VLANs, and InstaMesh® settings.

b.   HUGHES 9201 BGAN Terminal

This BGAN satellite internet access device unit provides both the connection to the Internet via satellite connection and WLAN capabilities. The performance of a WLAN network will be influenced by several factors including the number of users on the network, the location of the antenna, the distance

from the antenna and the degree of blocking from buildings and other infrastructure. Typical operating ranges are 200–300 meters outdoors and 30–60 meters indoors. The performance degrades gradually as the signal strength decreases. This device is discussed further in the next section.

3. SATCOM

The HFN model uses SATCOM as the primary backhaul method to connect with the Internet Service Provider (ISP) or backbone. The choices to connect are via BGAN or VSAT and as previously discussed, certain advantages and disadvantages for each method exist. This section discusses the two methods and focuses on the specific equipment used during the demonstration.

Three different BGAN units were used during the demonstration, two stationary and one mobile. Each unit was used to demonstrate different capabilities. For example, the mobile BGAN unit was used to send teams to a remote area and to establish a video or chat link with the rest of the responders. A stationary BGAN with Wi-Fi capabilities was used to establish a connection and make that connection available to a group of users with Wi-Fi enabled devices without the need for any additional equipment.

The BGAN LaunchPad is used to access and configure all BGAN units, which is a software interface. This interface provides the step-by-step procedures for setting up the unit, and the capabilities to configure the unit to meet the user requirements. The interface is also used to register the BGAN units with the network.
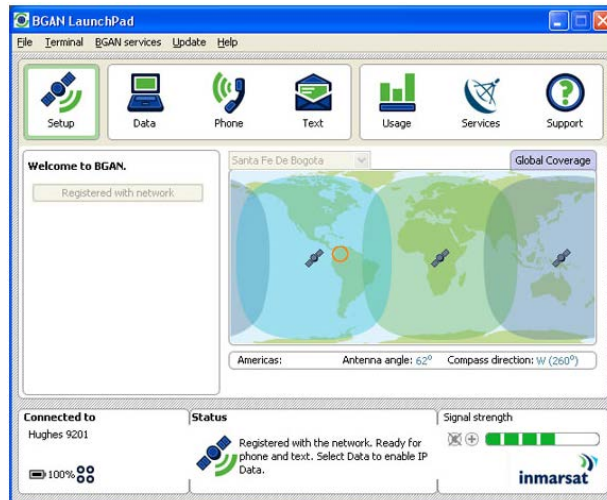
Figure 6.   BGAN LaunchPad

a.   HUGHES 9201 BGAN Terminal

The Hughes 9201 is a fully IP-compatible terminal certified for operation on Inmarsat's BGAN global communications service. Rugged and easy to use, the 9201 enables simultaneous IP packet and circuit-switched data communications via standard USB, Ethernet, ISDN, and 802.11 WLAN interfaces. The main features are as follows.

- 492 kbps IP data (transmit and receive)
- ISDN voice (4 kbps)
- ISDN data (64 kbps)
- Allows simultaneous use of all interfaces (Ethernet, USB, ISDN, and WLAN)
- WLAN access point
- Multi-user capability (up to 11 simultaneous sessions)
- Selectable Quality of Service (32, 64, 128, or 256 kbps)

41

Figure 7.   HUGHES 9201 BGAN Terminal

b.   *Thrane & Thrane EXPLORER 300*

This device is a highly compact, robust designed unit. It comprises a single unit incorporating a transceiver and an integral antenna. Due to the size and weight, this unit is the preferred choice for single users frequently on the move.

- 240/384 kbps IP data (transmit and receive)
- Quality of Service 32, 64 kbps send and receive

Figure 8.   Thrane & Thrane EXPLORER 300

c.   Harris Corporation RF-7800B-VU104

This unit was used to meet the mobility requirement of the demonstration. Designed to enable mounting on a vehicle and continuously track satellites to maintain connectivity. The connectivity is maintained as long as LOS is maintained to the satellite.

- 492 kbps IP data (transmit and receive)
- ISDN voice (4 kbps)
- ISDN data (64 kbps)
- Allows simultaneous use of all interfaces (Ethernet, USB, ISDN, and WLAN)
- Multi-user capability (up to 11 simultaneous sessions)
- Selectable Quality of Service (32, 64, 128, or 256[2] kbps)

---

[2] 256 kbps is only available at elevation angles > 45.

Figure 9.   Vehicle Mounted Harris Corporation RF-7800B-VU104 BGAN Unit

4.   VSAT

The VSATs used during the demonstration was a .95 meter VSAT terminal mounted on a trailer. However, it was only operational during the first part of the demonstration. Later, technical problems prevented its use. As an alternate source, the command vehicle provided the VSAT connection for the remainder of the demonstration.

The trailer mounted VSAT is one of two owned by the County of Monterey. A custom built trailer with components from various sources, the primary components of the trailer include a 0.95 meter diameter VSAT type terminal from DATASTORM model XF2 and controlled by a MotoSAT D3 controller, direct modem, router, power source and cabling.

Troubleshooting the problems with the trailer took too much time with very limited operational time. The goal was to test the trailer in this environment in which a trailer would have to be taken to a remote area via rough roads. Unfortunately, however, the trailer never operated long enough to perform the test. On the positive side, when a link was established, the performance was very good.

Figure 10.   County VSAT Trailer

5.   WiMAX

To demonstrate the capabilities of WiMAX technologies, a combination of Redline radios with Hyperlink antennas was used. This configuration allowed a quick setup using bike stands to hold the radio/antenna in position. The power source varied depending on location. At the AMSP, the Solar Stik™ was used until the load exceeded the capacity of the system. At the Old Coast Road, a generator was used, and at the NPS site, shore power was used. To make the setup of the radios easy, the NPS HFN team tested and configured the radios in the HFN lab prior to the exercise. This step was essential for the radios to work as expected in the field. The actual setup in the field took only a few minutes as it was only necessary to connect all the wires, power the radios, and then point the antennas. Each radio has a built in speaker that when two radios are talking to each other gives a signal. The better the connection, the faster the tone of the chirp signal. The WiMAX links were established using a Redline radio and Hyperlink antenna. The radios had the following settings.

- Subnet Mask: 255.255.255.0

- Gateway: 192.168.25.1
- DNS: 8.8.8.8

Figure 11.   WiMAX Radio/Antenna Setup at Old Coast Rd.

6.   Power

A reliable source of power is essential for the demonstration. The HFN model already includes the most reliable source, which is a gas-powered generator as the primary source of power. It also includes alternative sources, such as solar or wind generators. This section provides an overview of the power sources used for the IPC3 demonstration.

a.   *Gas Generators*

Ideally, gas generators would be the backup source of power for the HFN model to prevent the dependence on a fuel source to establish and maintain an HFN. The location of the demonstration was not ideal to use the alternate sources of power; therefore, generators were the primary source. The equipment used was a Honda EU 2000i, because it was easy generator to use

and had other characteristics, such as weight and size that fit right in with the HFN model. Table 7 shows the full list of specifications.

An additional consideration to remember that must be part of the HFN model is that most of the electronic equipment comprising the HFN model has very small tolerances for fluctuation in power. When power fluctuates outside the tolerances, the equipment will have trouble operating normally or not at all, and in some instances, it can be damaged. For this reason, when choosing a generator, chose one that can provide stable power over the ranges required.

Honda EU 2000i	
Engine	Honda GX100
Displacement	98.5cc
AC Output	120V 2000W max. (16.7A) 1600W rated (13.3A)
Receptacles	20A 125V Duplex
DC Output	12V, 96W (8A)
Starting System	Recoil
Fuel Tank Capacity	1.1 gal
Run Time per Tankful	4hrs. @ rated load, 9.6 hrs. @ 1/4 load
Dimensions (L x W x H)	20.1" x 11.4" x 16.7"
Noise Level	59 dB(A) @ rated load 53dB(A) @ 1/4 load
Dry Weight	46.3 lbs.

Table 5.   Generator Specifications (From: Honda, 2012)

b.   Solar Stik™ Breeze

The Solar Stik™ Breeze is a hybrid system that combines wind and solar power, which is ideal for locations were solar and wind potential exists. The system can generate up to 1.5 kW-h of power per day, enough to power

equipment with light or medium power requirements like computers and communications equipment. This system is designed to increase its capacity with additional solar panels or battery packs (Stick, 2012).

The advantage of the system is the ease of use and no need for a fuel source. The disadvantage is the size and weight. The battery packs are very heavy (100 lbs.) and the wind generator and solar panels require a strong and stable platform that even constructed from aluminum adds considerable weight and volume to the system.

Figure 12.   Alternate Power Sources (Solar Stik™ and Solar Blankets)

G.   NETWORK

1.   Background

The common network topologies include point-to-point, star and mesh networks. The point-to-point topology is used when a single channel per carrier is all that is needed and is typical of terrestrial WAN connections. The star topology is used when the number of users is dispersed in an area and communications or data transfer among all users is enabled by routing the traffic through a central

gateway or hub. The mesh network is a network in which nodes or devices are connected to every other node, which makes it fault tolerant, because when one node fails, the traffic can be routed through an alternate route.

Figure 14 shows the three primary links on the HFN model. These three links provide the last mile connection, the BGAN and VSAT units provide a link to the internet backbone via a satellite connection, see figure 2. The point-to-point link is used to extend the network to remote areas where LOS exists, and then a Wi-Fi mesh or a star topology can be established with one Wi-Fi device or a mesh. The HFN model uses WALNS, which makes the model flexible and inexpensive. The model uses a combination of all three topologies mentioned above. To establish a local group of users, the star topology is used in which a Wi-Fi provides access. A point-to-point topology is used to extend the network to areas beyond the reach of Wi-Fi capabilities, in this case, WiMAX technology is used. Last is a meshed network in which Wi-Fi technology with a capability to create a mesh is used to build a network that continuously changes as nodes move.

Point-to-point
WiMAX Link

Star topology, PDA's and laptops
connected via the Wi-Fi capability
of HUGHES 9201 BGAN unit

Mesh topology created
with Rajant
BreadCrumb®
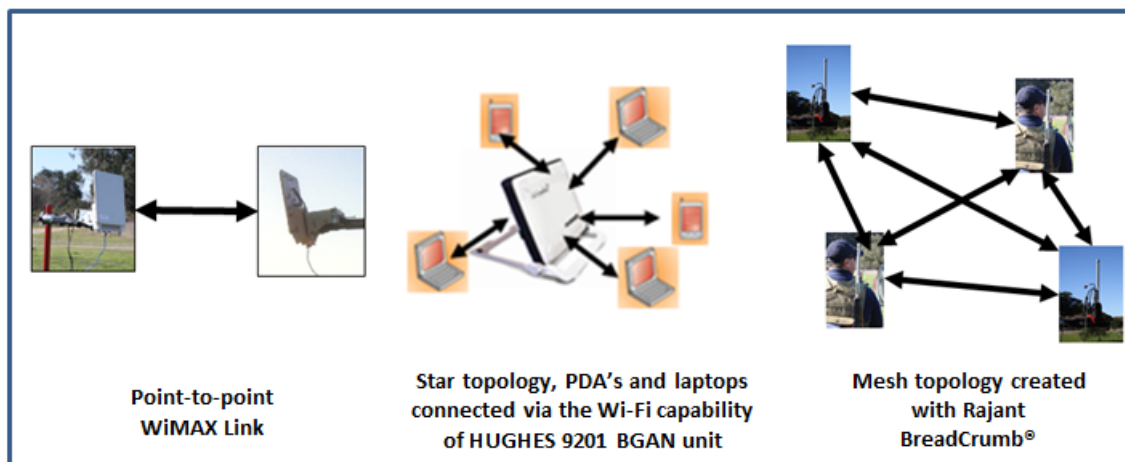
Figure 13.   Samples of Topologies Used on the HFN Model

During the demonstration, Andrew Molera State Park (SMSP) and the NPS Facility at Point Big Sur were designated as the VSAT/BGAN locations. The

VSAT services at these two sites could be accessed via the County VSAT trailers or the command vehicle. The BGAN services could be accessed using any of the BGAN units available. The WiMAX links were established to connect all locations and the Wi-Fi mesh was established at each location to provide users access. Additionally, a mobile BGAN was available to reach remote areas where line of sight for a WiMAX link was not possible and a mobile Wi-Fi configuration was tested to provide live video while walking through the Wi-Fi coverage area.

Figure 14.   Demonstration Network at Big Sur

Equipment	AMSP	Light House	Coast RD	NPS Point Sur
WiFi	Rajant BreadCrumb® ME2	Rajant BreadCrumb® JR	N/A	Rajant BreadCrumb® ME2
WiMAX	Redline AN-80i 5.8 GHz Panel Antenna: Hyperlink HG5822P IP: 192.168.25.2	Two Redline AN-80i 5.8 GHz Panel Antenna: Hyperlink HG5822P IP: 192.168.25.5 And 192.168.25.6	Redline AN-80i 5.8 GHz Panel Antenna: Hyperlink HG5822P IP: 192.168.25.3 And 192.168.25.4	Redline AN-80i 5.8 GHz Panel Antenna: Hyperlink HG5822P IP: 192.168.25.7
Power	Solar Stik™, Solar Blankets, Generators & SLS Command 5390	Generator	Generator	Shore Power Nemesis
Satellite Gateway	BGAN: Hughes 9201, and Thrane & Thrane Explorer 300 VSAT: SLS Command 5390 and County trailer		BGAN: Harris RF-7800B-VU104 (military)	BGAN: 9201 VSAT: County trailer
Computer	5 Windows Laptops 1 Android Tablet	1 Windows Laptop	1 Android Tablet 1 Windows Laptop	1 Android Tablet 3 Windows Laptops
Applications	Skype, Email & NICS	Skype, Email & NICS	Skype, Email & NICS	Skype, Email & NICS

Table 6.   Demonstration Network Components

H.   APPLICATIONS

Two types of applications were used during the demonstration, required, or applications used by the ERC, and optional applications that enable better communications. The first category includes Next-generation Incident Command

System (NICS), Radio Interoperability System (RIOS), and Skype as the optional application that enabled the team to test the equipment and to communicate between the different nodes.

1.   Next-Generation Incident Command System (NICS)

> NICS provides collaboration and communication capabilities across all echelons of responders; enhances the quality and accessibility of sensor data; and integrates location data for resources, vehicles, and personnel. (Breimyer, 2011)

NICS, previously known as Lincoln Distributed Disaster Response System (LDDRS), is an integrated sensing and command-and-control system, developed to enable a coordinated and collaborative disaster response by improving situational awareness. Wildfires in California over the past decade have showed how essential a system like NICS is to the response community. As a result of those fires, the Massachusetts Institute of Technology (MIT) Lincoln Laboratory in partnership with the California Department of Forestry and Fire Protection (CAL FIRE) worked to develop it. The primary purpose of NICS is to enhance the interoperability of the many responders to a disaster and to improve the situational awareness by combining information from many different sources and sensors into one system.

Figure 15.   NICS Combines Sensors with Communications and Visualization Technologies in a Net-Centric Architecture to Enable Real-Time, Shared Situational Awareness During Response Operations. (From Breimyer, 2011)

NICS is designed to collect information from all available sources, real time video, weather stations, existing geographical information and any other information communicated through the available resources to maintain/update

the COP. Data is collected and displayed using a web-based, open standards platform that displays a map-based environment and is accessible via the Internet.

2.   Radio Interoperability System (RIOS)

Monterey County and the local Fire departments use Radio Interoperability System (RIOS) as the primary program to coordinate

communications among agencies and among different systems. The system provides a graphical user interface (GUI), which is an intuitive multi-media landscape that graphically illustrated voice, and video patches of user groups (SyTech, 2012). RIOS decodes, translates and transmits to virtually all types of communication devices and connected networks. With RIOS, radios, phones, computers and video are brought together with software and hardware ideal for interoperable communications, multi-site networking and advanced communications relay. RIOS is the bridge between the diverse communication resources and the workforce supported (SyTech, 2012).

Figure 16.   RIOS Graphic User Interface (From: SyTech, 2012)

3.   SKYPE

Skype is an Internet service that allows users to video conference, audio conference, chat message, and send files all at the same time. The basic service is free with the option to purchase services with more capabilities. For the demonstration, only the basic (free) services were used. Skype uses peer-to-peer (P2P) network technology to establish and route connections directly

between computers instead of using a centralized server (Max & Taylor, 2006). This application was chosen due to its simplicity to install and use. With Skype, it is possible to connect across continents, borders, countries, and time zones to make clear voice calls, send instant messages, transfer files, and make video calls almost anywhere in the world for free (Max & Taylor, 2006).

Most of the personnel participating in the demonstration were already familiar with Skype and the county has already established an account for the command vehicle. Ten additional accounts were established for use during the exercise and became the primary means of communications for the demonstration. It also served to test the connections between each node.

THIS PAGE INTENTIONALLY LEFT BLANK

V.   DEMONSTRATION RESULTS

A.   ALTERNATE POWER

The demonstration of the alternate power was planned to be done two or more times. The first time was successful. Every participant had an opportunity to see the setup and a brief was given that covered all the major components of the system. The setup turned out to be more labor intensive than expected due to the size and weight of all components, and for that reason, the alternate power was not used in the other locations. Although the goal of deploying the system several times and having hands on training in which the ERC members set up the system with supervision from NPS HFN group was not possible, it was not a total failure. The advantage of setting up the system at the base camp was that it provided opportunities for every participant to look at the system and NPS staff had several opportunities to explain how the system worked.

Prior to the exercise and during previous demonstrations, the HFN staff developed a numbered system for all alternate power components and connections. During the setup, the HFN team found that the numbering system was a little confusing and talked about improving it by color coding the cables, which was not tried and is left as a possible method to improve the setup of the system.

Initially, most of the load was put into the alternate power system. However, this load reached capacity, and it was necessary to augment it with gas generators. The power requirements or loads to adequately run all HFN systems all day were not measured, nor was the amount of power generated by the alternate power system. This should be an area of focus for future field experimentation to determine the capacity needed to run all HFN systems for a 24 hours period.

B.   MESHED WI-FI (802.11)

Several product options exist to establish a Wi-Fi mesh but at the time of the demonstration, only Rajant BC were available. The goals of the demonstration were to demonstrate the capability of creating a mesh for a group of users at base camp, and alternate locations, and to use this mesh network to communicate during the exercise. A second goal was to eventually compare/contrast BC with alternate meshed Wi-Fi technologies specifically with Persistent Systems Wave Relay, which is a product being researched by other at NPS.

In preparation for the exercise, the NPS HFN team conducted several tests setting up and configuring the BCs. One issue that arose concerned whether the BGAN or the BCs should provide DHCP. Whether to use the BC's 10.10.10.x IP scheme or even whether or not to use static IP addresses was addressed. After discussing this topic with the Rajant engineers, it was decided that using a static IP addresses would generate new problems when units would come/go from the network, and thus, would create new points of failure and limit the self-forming/self-healing nature of these meshed WiFi devices.

The Rajant BC proved to be very effective in the field. A combination of BCs was deployed to meet the specific exercise needs. During the demonstration, two representatives from Rajant were available and helped by providing advice and technical expertise.

The BC was set up four times. The average time to have the BCs working was 10 minutes. It took longer to move to the desired location that it did to set up the BCs. The following reasons made it possible to set up in that amount of time: Prior to the deployment of the BCs, each unit was tested and the proper configuration loaded. The personnel setting up the BC only had to connect the wires, provide power and turn it on.

During the first setup, an attempt was made to connect the Point Sur lighthouse with NPS Point Sur facility using BCs. See Figure 16. The distance

between these two points was approximately 600 meters. This connection worked fine, which proved that the BCs could complete the long haul link combining both the WiMAX and Wi-Fi components. Also discovered was that the BCs at base camp provided coverage all the way to the site on Old Coast Road, and was tested by sending pictures and connecting via Skype with a Toshiba Thrive, tablet computer. These two tests provided a good example of the extended capabilities of BCs over regular Wi-Fi products.

Up to this point, the BCs proved to be a reliable, easy to use technology to set up a meshed network. During these tests, all nodes remained stationary so that the self-healing capability of BCs was still not tested. To test this capability, mobile configurations would need to be used.

The first mobile test was performed by connecting one BC to the mobile BGAN mounted on a SUV. During this test, starting at the NPS Point Sur facility by connecting with AMSP via Skype, and then driving towards AMSP, the connection remained active until the LOS was clearly lost. It was then reconnected when getting closer to AMSP. If more BCs had been placed along the route, the connection would have remained active just as a cell phone moving from cell to cell. The last test was performed using a combination of BCs with an IP camera mounted on a vest. This test was performed at the base camp and NPS Point Sur. When walking around the camp, the connection remained active even when walking through foliage.

The BC's also had a capability to geo-reference, or to pinpoint, the location of each BC. This capability could be an exceptional way to maintain command and control of all assets during an emergency. An example is keeping track of all firefighters during a wild fire. Knowing the location of every individual could help in planning the strategy to fight the fires better. Additionally, it would also be possible to find an injured firefighter. Unfortunately, this capability was not tested due to the limited time and resources available.

C.   WIMAX BRIDGE (802.16)

As in the Wi-Fi mesh, preparation was very important. Ensuring that the radios had the proper configuration and were properly labeled was one of the keys to success as was discovered during preparations and previous demonstrations. In addition the radios must be configured as master or slave before deployment. Installing the wrong radio at the wrong location will not work. A representative from Future Technologies who was a very experienced engineer with the WiMAX technology, provided additional help, and more specifically, with Redline radios. He was invaluable by walking the NPS team through the Redline GUI and choosing the best settings for the location.

The total number of radios used for the long haul link was six, one at AMSP, two at the Old Coast Road, two at the Point Sur Lighthouse and one at NPS Point Sur facility. See Figures 12 and 16 earlier in chapter IV.

On the second day, the final link of BCs was replaced with the other two Redline AN-80 radios with ease. The link throughput measurement was determined to be greater than 40 MBPS! This measurement is a phenomenal throughput rate, although of course, the bottleneck was the VSAT or BGAN satellite access to the IP backbone.

The only time a link was lost occurred when the wind knocked down one of the radios at the Lighthouse. The radios were previously weatherized the units with plastic bags to prevent moisture buildup due to expected rain. The antenna, which is a foot square, and the plastic bag acted like a sail and the wind easily knocked down the setup. The radio was not damaged, and as soon as it was back up, it was back on line. A lesson learned here was to bring sandbags or anchors and rope to secure the setup.

The Redline WiMAX gear proved to be a very simple Ethernet bridging technology. No problems occurred with this gear probably due to proper planning. The best thing done was to guarantee all the radios had the right

configuration and had labels to ensure it was known which radio was to be deployed at each location.

D.   SATCOM

The three IP connectivity goals of the demonstration were to set up and maintain communications using the various units available including the stationary BGAN units, a mobile BGAN, and lastly, a connection using the VSAT County-owned trailers. The configuration to extend the network varied in two ways. First, the BGAN unit was directly connected to one of the WiMAX radios and the network was extended to the other sites in a similar manner. In the second configuration, the BGAN unit was connected to the Wi-Fi devices and the network was extended to the Wi-Fi mesh. The mobile BGAN unit was connected to a Wi-Fi device that allowed connection to one or more users in the vehicle.

1.   BGAN

The BGAN unit's performance was very good, set up was easy and it took only a few minutes to establish a connection and to provide access. The first unit demonstrated was the Hughes 9201 BGAN unit. This unit is one of the preferred pieces of equipment for the HFN model due to its capability to provide access instantaneously to a satellite and serve as a Wi-Fi hotspot, which provides Internet access to an area covering approximately 100 meters, enough to cover the entire base camp. The BGAN on the move proved to be a reliable system as well, for this we used the Harris Corporation RF-7800B-VU104 BGAN unit mounted on an SUV.

2.   VSAT

The Monterey County VSAT trailers had been unused for a long time. In preparation for the demonstration, the NPS HFN team worked to get the trailers back online, replacing most of the wiring, updating the software, and replacing some of the components. By the time of the demonstration, one of the trailers had some success in establishing an Internet connection and maintaining it.

However, even under the best of circumstances, the system continued to perform poorly. One day it would work just fine and would only take a few minutes to become connected, and the next day, it required troubleshooting. The first two days were scheduled to be a trial run of all the systems including the VSAT trailers. On the first day, the working trailer was utilized and an Internet connection was established immediately. That system was used to access the Internet for most of that evening. That night, the trailer was left open to the elements, and the following morning, a noticeable amount of moisture was found on all open surfaces. After all moisture was dried, the trailer was powered and did not work. Troubleshooting for a few hours was unsuccessful and the trailer was stowed back for further troubleshooting after the demonstration.

As an alternate plan, the VSAT services from SLS Command 5390 were used for the rest of the demonstration. This system performed exceptionally.

E. APPLICATIONS

This portion of the demonstration was to ensure that the HFN concept with the technologies used could handle the demands of the ERC. The first requirement was to establish access to the web-based application developed specifically for the ERC by MIT/Lincoln Labs (NICS). The second objective was to ensure the ERC communications team had access to RIOS, an essential part of the communications management plan. The third was to provide basic communications links using any available COTS application that facilitated voice, video and chat. For this last objective we chose Skype.

1. Next-Generation Incident Command System (NICS)

In preparation for the demonstration and in collaboration with Lincoln Labs, the NPS HFN team setup 10 NICS user accounts on a development server at Lincoln Labs. These accounts were tested in the HFN lab and it was confirmed that all worked using the NPS network. Once on the field, as soon as a satellite connection was established, several attempts were made under all scenarios, and with a combination of laptops and tablets. None were successful. The

system was accessed but once the login portion was completed, it never proceeded past that portion. Every attempt had the same result. Thus, this portion of the demonstration was not successful. This was due to the latency of satellite connectivity and the ability of NICS to handle this latency.

2. Radio Interoperability System (RIOS)

The communications personnel were able to access RIOS successfully and to manage the communications equipment using one of the BGAN units as the primary access to the Internet. No detailed measurements were taken to evaluate the exact performance of this system. An acceptable performance was being able to access the system and to manage the various radios used during the demonstration.

3. SKYPE

Ten accounts were established for the exercise. Additionally, the SLS Command 5390 had its own account. Testing was successful in various scenarios, from static laptops to mobile units. In each case, the voice had good quality and the video was acceptable. Whenever the communication was experiencing some decay in quality, the users had an option to turn off the video, which immediately improved the quality of the voice. Perhaps the best result was with the mobile BGAN unit. Using this configuration provided the best possible intelligence to the command vehicle by providing live video feeds of the area and maintaining voice communications at the same time. The file transfer capability was not tested.

F. SUMMARY

The NPS IPC3 field demonstration provided an excellent opportunity to introduce the HFN concept to the ERC. All participants became familiar with the HFN model and many had an opportunity to help set up the primary components. The objectives of the demonstration turned out to be very demanding with the amount of time and resources available. Testing and measuring the performance

of all equipment was not optimal; therefore, the conclusions are not definitive about specific capacities and loads for the system. Additionally, with the exception of NICS, the other applications including RIOS, Skype and Internet browsing programs had no impact on the system, which was an indication that the maximum load capacity was not reached. Success was defined as the initial establishment of communication links among all the components and the successful transmission of IP traffic; in this case, success was defined as a successful Skype session. Additionally, the ability to maintain connection while moving was proven with the use of Skype. The conclusions do not provide enough information to make specific recommendations on what capacities each system has to carry the traffic generated during an actual scenario.

The overall results are very positive; this first demonstration exercise has proven that the HFN model is a good fit for the ERC. It performed well in the environment needed and it proved that the members of the ERC could learn to set up and operate the system in a relatively short time. Further research should be conducted in which the performance of each component is better examined and should include testing the traffic load capacity of the systems and the power load in the alternative power system.

One particular application that requires further attention is NICS, since this application is specifically developed for the ERC. Further testing needs to be conducted to determine what is preventing NICS from working using a BGAN unit. In preparation for the exercise, NICS was tested in the HFN lab several times and it worked. But we noticed that it took longer than any other application to load and to respond, which is probably an indication that NICS requires a high bandwidth capacity and a very fast processor to run as intended. Unfortunately, it is not ideal for a system intended to be used in the field, and potentially with smart phones, tablets and laptops.

The Monterey County VSAT trailer proved to be a disappointment, although the concept is ideal for the ERC community for the portability capability. The trailer can be towed to a remote area that can't be reached by the command

vehicle to provide a higher capacity to the ERC when a BGAN unit is not enough. The trailer configuration did not perform well in the field. In preparation for the demonstration, several tests were conducted. In most cases, the VSAT was able to obtain a connection in less than 10 minutes. However, the tests in the field worked only during the initial setup, and provided access to the users during the first day. However, the trailer and its components were later exposed to the elements overnight and moisture got in to the electronics and made the trailer inoperable. A few hours were spent troubleshooting, drying and connecting/disconnecting all components with no success. The VSAT trailers proved to be unreliable. But in previous experiments, other self-contained VSAT units proved to be easy to set up and were more reliable. The NPS HFN team spent more than 40 hours troubleshooting or repairing these trailers only to discover how vulnerable they were to the elements.

A second test was planned that would have taken the trailers on a remote road to test for sturdiness. Had the trailers worked, it would have been necessary to take the trailer on a rough road to a remote area to see how the system would survive that kind of punishment. It is probably likely that this kind of punishment would also have rendered the trailers inoperable.

THIS PAGE INTENTIONALLY LEFT BLANK

VI. CONCLUSIONS

The primary objective of this research was to find an alternate communications solution for the ERC and the demonstration proved that the HFN model is a good way to achieve that goal. The benefit of configuring a system with COTS makes it easy for any organization to configure the right fit for their needs. The equipment used is only an example of each technology: Meshed Wi-Fi, WiMAX and Satcom. The technologies will continue to evolve and the potential will always exist to find more capable systems. When deciding on a particular technology, the users must consider not only the costs, but also the maturity of the technology and the stability of the manufacturers, to ensure technical expertise is available in the future.

The HFN concept is ideal to meet the requirements for mobility and scalability needed by the ERC. The combination of COTS technologies makes it an inexpensive solution compared with the cost of a system that provides similar capabilities, i.e., command vehicles. The technologies used during the demonstration are not the only solutions; the proliferation of wireless devices has increased the number of companies investing in developing both the WiMAX and Wi-Fi technologies to meet the demanding needs of users. Additionally, the culture within the ERC seems to be one already prepared to change by incorporating better technological solutions to make its jobs easier; therefore, adding the HFN model to its practices should not be extremely difficult.

A. RISKS

The demonstration conducted yielded positive results. However, significant risks are associated from drawing conclusions from one demonstration. These risks include (1) moving ahead without sufficient evidence and understanding, (2) prematurely settling on an approach, (3) confining explorations to the industrial-information age border, (4) progressing by trial and

67

error as opposed to being guided by theory, and (5) failing to capitalize on the creativity present in the force (Alberts & Hayes, 2005).

Considering the resource constrained environment, it is recommended that a broader campaign be embarked upon in which the ERC has an opportunity to integrate better the technological and organizational factors of HFN into its normal operating practices. Every emergency response community is likely looking for solution to the same problem. Therefore, it would be ideal if statewide or nationwide responders can coordinate a campaign of experimentation. Thus, the ERC has capacity to explore a broader range of technologies on a greater set of conditions, and as a result, discover the best technological and business practices or organizational solutions to a common problem.

B.   LESSONS LEARNED

Practice, practice, practice… the best lesson was to ensure the equipment is deployed in advance, that all the hardware is in working condition, that the software is updated, and that the systems are compatible, which is only possible by practicing and setting up the system repeatedly. It cannot be expected that the system would be functional if left sitting for long periods. One example is the County VSAT trailers. Even after troubleshooting and updating all the software and cabling, for example, the trailers never performed as expected.

C.   FUTURE STUDY

This thesis provided a good overview of the capabilities of the HFN model and the potential benefits it may provide to the ERC. Further research is needed to ensure that all applications, such as NICS, have the capability to run using the HFN concepts, which will require specific testing and measuring of the resources needed by all applications and to stretch the HFN model capabilities to its limits. Additionally, in this research the organizational impact of implementing the HFN concepts at the ERC is viewed from a very broad perspective, additional research should be conducted to find the economic and organizational challenges of implementing HFN concepts.

1. ERC Applications

The ERC uses a number of applications that enable an efficient C2 environment (NICS, RIOS, WebEOC', etc.). These applications provide management personnel the ability to track changes in the environment and to track the activities of first responders. At the same time the first responders use these applications to maintain situational awareness during the disaster. Future research is required to reliably predict the capability or lack-off capability to reliably run these applications with the technological components of the HFN model.

2. Geo-location and Vital Signs Sensors

The establishment of a meshed network opens up the possibility to maintain connectivity with all first responders on the field. It is unlikely that all first responders will carry a computer or other device to access the network. However a meshed network can be used to track the location and other vital signs of first responders with nonintrusive Wi-Fi enabled sensors carried by each first responder. Future research can provide the framework to incorporate these sensors with the HFN concepts.

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF REFERENCES

Alberts, D. S., & Hayes, R. E. (2005). *Campaigns of experimentation: Pathways to innovation and transformation.* Washington, DC: DoD Command and Control Research Program.

Alberts, D. S., & Hayes, R. E. (2009). *Code of best practice for experimentation.* Washington, DC: DoD Commnad and Control Research Program.

Andrews, J. G. (2007). *Fundamentals of WiMAX, understanding broadband wireless networking.* San Franciso: Prentice Hall.

Arifumi, U., Mixumoto, T., & Okumura, T. (2011). How geeks responded to a catastrophic disaster of a high-tech country. *Preceedings of the Special Workshop on Internet and Disasters (SWID 11)*, 8.

Barabasi, A. L. (2002). *Linked the new science of networks.* Cambridge, MA: Perseus Publishing.

Bordetsky, A., & Netzer, D. (2010). Testbed for tactical networking and collaboration. *The International C2 Journal.*

Breimyer, P. W. (2011). *Next-generation incident command system.* Retrieved from Lincoln Laboratory, Massachusetts Institute of Technology website: http://www.ll.mit.edu/publications/technotes/TechNote_NICS.pdf

Capra, F. (1996). *The web of life.* New York: First Anchor Books.

Chertoff, M. (July, 2008). *National emergency communications plan.* Retrieved from Department of Homeland Security website: http://www.dhs.gov/xlibrary/assets/national_emergency_communications_plan.pdf

Comfort, L. K., Ko, K., & Sagorecki, A. (2004). Coordination in rapidly evolving disaster response systems. *American Behaivioral Scientist*, 295–314.

Department of Defense. (2007). *Department of Defense information sharing strategy.*

Denning, P. J. (2006). Hastily formed networks. *Communications of the ACM*, 15–20.

Denning, P. J., & Hayes-Roth, R. (2006). Decision making in very large networks. *Communications of the ACM*, 19–23.

Dilmaghani, R. B., & Rao, R. R. (2008). An ad hoc network infrastructure: Communication and infromation sharing for emergency response. *IEEE*, 442–447.

DoD. (2009, April 30). *DoD issuances.* Retrieved from DTIC website: http://www.dtic.mil/whs/directives/corres/pdf/822002p.pdf

DoD. (2012, January 9). *Defense strategic guidance.* Retrieved from http://www.defense.gov/news/Defense_Strategic_Guidance.pdf

Garcia, G. O., & Joseforsky, D. C. (2004). *Transformational communications architecture for the unit operations center (OUC); Common aviation command and contol system (CAC2S); and command and control on-the-move network, digital over-the-horizon relay (CONDOR)* (master's thesis) Naval Postgraduate School, Monterey CA.

Government Accountability Office. (2006). *Statement by comptroller general David M. Walker on GAO's preliminary observations regarding preparedness and response to Hurricanes Katrina and Rita* (GAO-06-365R). Washington, DC: Government Accountability Office.

Honda. (2012). *Generators.* Retrieved from http://powerequipment.honda.com/generators/models/eu2000i

Horan, T. A., & Schooley, B. L. (2007). *Time-critical information services.* New York, NY: Communications of the ACM.

Klemek, B. (2011). *Reliz fire (incident #CA-BEU-2787) after action/corrective action report.* Sacramento CA: California Depeartment of Forestry & Fire Protection.

Lim. M. H., & Ng, M. Y. C. (2007). *Hastily formed network* (master's thesis). Naval Postgradudate School, Monterey, CA.

Manoj, B. S., & Hubenko Baker, A. (2007, March). Communication challenges in emergency response. *Communications of the ACM*, 51–53.

Marshall, B., & Wilson, T. V. (2001, April 30). *How WiFi works.* Retrieved from HowStuffWorks.com website: http://computer.howstuffworks.com/wireless-network.htm

Max, H., & Taylor, R. (2006). *Skype: The definitive guide.* Indianapolis, IN: Que.

Pfeifer, J. W. (2005). *Command resiliency: An adaptive response strategy for complex incidents* (master's thesis). Naval Postgraduate School, Monterey, CA.

RAJANT. (2011, November 15). *Portable wireless mesh networks.* Retrieved from http://www.rajant.com/

San Diego State University. (2012, Febrauary 6). *X 24.* Retrieved from Viz Center website: http://vizcenter.net/x24/dash.html#&panel1-4

Scott, M. F., & Charles, B. W. (2005). Proceedings of the First IEEE Workshop on Disaster Recover Networks: *Rapidly-Deployable Broadband Wireless Networks for Disaster and Emergency Response.* New York, NY.

Self-organization. (2011, Octover 30). Retrieved from Wikipedia website: http://en.wikipedia.org/wiki/Self-organization

Starbird, K., & Palen, L. (2011). Proceedings of the ACM: *Voluntweeters: Self-Organizing by Digital Volunteers in Times of Crisis*, 1072–1080.

State of California. (2010). *2010 Strategic fire plan for California.*

Steckler, B. (2005). *The nine element HFN puzzle.* Retrieved from Hastily Formed Networks website: http://faculty.nps.edu/dl/HFN/puzzle_piece/puzzle_content.htm

Steckler, B. (2012). *BGAN and VSAT don't leave home without them* !!! NPS HFN Research Group.

Steckler, B., Bradford, B. L., & Urrea, S. (2005). *After action report and lessons learned from the Naval Postgraduate School's response to Hurricane Katrina.* Monterey CA: Naval Postgraduate School.

Stick, S. (2012). *Solar Stik™ 100 breeze & power pak system.* Retrieved http://www.solarstik.com/products-solutions/terra-packages/solar-stiktm-100-breeze-power-pak-system

Sutton, J., Palen, L., & Shklovski, I. (2008). *Backchannels on the front lines: Emergent uses of social media in the 2007 Southern California wildfires.* Washington, DC.

SyTech. (2012, January 28). *RIOS interoparability.* Retrieved from http://www.sytechcorp.com/products/RIOS_Interoperability

Walker, D. M. (2006). *Hurricane Katrina: GAO's preliminary observations regarding preparedness, response, and recovery* (GAO-06-442T). Retrieved from Government Accountability Office website: http://www.gao.gov/new.items/d06442t.pdf

Yarali, A., Ahsant, B., & Rahman, S. (2009). Wireless mesh networking: A key solution for emergency & rural applications. *Advances in Mesh Networks, 2009. MESH 2009. Second International Conference* (pp. 143–149). IEEE.

APPENDIX A. DEMONSTRATION EXERCISE TIMELINE

13 December 2011	
1200	STARTEX: NPS IPC3 Team Loadout at NPS and transport to and set up camp at Andrew Molera State Park' Campground
1700–2200	Team Bonding/Training/HFN and Virtualization discussions around the campfire at AMSP Incident Command Site
1800–1930	Chow at AMSP Campground Incident Command Site
14 December 2011	
0630–0900	Reveille and Chow (AMSP Incident Command Site)
0900	NPS IPC3 Team and Other Early Responders get word via email from Chief Walker to mobilize (official request process from state to federal gov't completed)
0900–1000	All Hands Transport/Begin HFN Setup at AMSP Parking Lot (hotspot), AMSP Campground and Pt Sur Navy EOC site (localized safety and operations briefs in situ) As appropriate collect data (power needs, network throughput, range of coverage for WiFi Mesh, etc.)
1030–1100	All Hands Safety and Operations Brief (at AMSP Campground)
1130–1400	NPS IPC3 Team and Salinas Fire department command vehicle 5390 (SLS Command 5390) Teams Set Up Comms, EOC In A Box, Alt Pwr, etc. As appropriate, collect data (power needs, network throughput, range of coverage for WiFi Mesh, etc.
1400–1600	Cross Training and Demonstrations

1630–2200	Daily Hot Wash:
	Team Bonding/Training/HFN and Virtualization Discussions around the Campfire at AMSP Incident Command Site
	NPS students brief on their technology responsibilities and activities for the day (and next day)
	Barreto briefs EOC in a Box and Solar Stik™ systems; Steckler briefs IPC3 Comms Package
	Salinas Fire briefs on capabilities of SLS Command 5390 Command Vehicle and RIOS LMRoIP system
	Chief Walker briefs on NICS situational awareness package
	Operations Brief for 6 December Events
1800–1930	Chow at AMSP Campground Incident Command Site
15 December 2011	
0630–0900	Reveille and Chow (AMSP Campground Incident Command Site)
0900–0930	Safety and Day's Activities Briefs
0900–1000	All Hands continue setting up, testing and cross training on all HFN systems
1000–1400	NPS IPC3 Team and Salinas Fire SLS Command 5390 Teams continue setup/training for Comms, EOC In A Box, Alt Pwr, RIOS, MESHED WIFI, WIMAX, VSAT/BGAN, etc. (taking time out to explain your systems to observers and those getting cross trained)
	As appropriate, collect data (power needs, network throughput, range of coverage for WiFi Mesh, etc.
1400–1600	Cross training and demonstrations
1600–1630	Daily Hot Wash
	Tear down campsites, gear pack out, clean-up areas
1730	ENDEX

APPENDIX B. EXERCISE INJECTS

	Inject	Response
1	A need has been stated to have radio communications from the ICP back to the County EOC in Salinas. The traditional radio relay means are not available	Use the RIOS on COM SLS Command 5390 to create and maintain radio communications from the incident scene to the EOC in Salinas as well as to the IPC3 event sites (AMSP Campground, AMSP Parking Lot, Big Sur Lighthouse Radio Relay Site and Old Coast Highway WiMAX Relay Site)
2	The IC has expressed the desire to have computer communications over a wide area surrounding the Basin Complex Camp. It has been determined that a WiMAX extension of the already established network should solve the problem	Establish and maintain a WiMAX extension of the existing network that will provide wider computer communications coverage to the Naval Facility at Point Sur
3	The Operations Chief needs to have computer communication with the Branch Directors near the fire's edge.	Set up Wi-Fi Mesh Network using several locations (AMSP Campground, Navy Facility at Point Sur, Radio Shack at Point Sur Light House and WiMAX relay point on hillside above AMSP campground). Provide internet access to those locations. Use NICS as the situational awareness tool of choice to communicate over the computer based connections.
4	The bandwidth need of the Basin Complex is increasing. A need has been identified to create redundancy between the VSAT link on COM SLS Command 5390 with the VSAT links being used elsewhere in the Basin Camp has been identified as a way to assist with the bandwidth needs. BGAN at any of the exercise sites is an alternate satellite broadband connection option if VSAT is not available	Create and maintain an intertie between the VSAT link on COM SLS Command 5390 and other VSAT links that have been established at the Basin Camp
5	Spot fires have been reported in the Bottcher's Gap Campground at the east end of Palo Colorado Road. The Plans Chief has requested first hand vide intelligence gathering from one of his Field Observer Teams (FOBS)	Respond to Bottcher's Gap Campground at the east end of Palo Colorado Road. Set up and beam back live video from the campground. Demonstrate On-The-Move BGAN with Meshed Wi-Fi and Skype video and/or standard web camera (as well as RIOS if possible/available)

	Inject	**Response**
6	A fire engine rollover has been reported in front of the Nepenthe Inn in Big Sur. The Safety Officer and Operations Chief have requested first hand video intelligence gathering from one of their FOBS	Respond to Nepenthe Inn on the west side of Highway 1 at the south end of Big Sur. Using On-The-Move BGAN and Meshed Wi-Fi, with Skype video or web video camera, set up and beam back live video from the turnout below the parking lot for the Nepenthe Inn to COM SLS Command 5390 or other nodes on the network
7	A large contingent of evacuees is gathering at the Big Sur Multi-Purpose facility. They want to occupy the area until the fire has been contained. The Liaison Officer (LOFR), the Monterey County Sheriff's Department and Operations Chief have requested first hand video intelligence gathering from one of their FOBS	Respond to the Big Sur Multi-Purpose facility on the east side of Highway 1 approximately 0.5 Miles south of the entrance to Pffiefer Big Sur State Park. Set up and beam back live video from the parking lot for the Big Sure Multi-purpose facility using any means available for connectivity and video broadcasting.
8	There is no power available at base camp, in an effort to conserve fuel the IC has declared that as much of the power as possible should be generated from alternative power sources	Set up an alternative power generating system in the Camp to run the ICT components in the area.
9	The COML for the Basin Complex has a communication problem. He has determined that a portable repeater deployment at the Big Sur Lighthouse would solve the problem	Set up a portable repeater at the Big Sur Lighthouse.
10	Monterey County uses the software product named Web EOC. In order to provide better communications between the ICP and the Monterey County EOC, the IC through the LOFR and the COML has requested that Web EOC be activated on the local network system and pushed to as many camp nodes/users as possible.	Activate the Web EOC software in as many computer terminals in the camp as possible.

	Inject	Response
11	Web EOC and NICS have now been activated on numerous terminals throughout the Camp. The IC and Monterey County OES staff wants to have a large contingent working the application. However, the problem is that the maximum allowable number of users at one time has not been determined. In order to provide the IC with a maximum allowable number of users, a test must be done to determine users and workload on the network and components	Conduct a workload test by putting the largest number of simultaneous users as possible on the system in an effort to test the ability of the in-camp system and the backhaul to handle workload.
12	The Operation Chief needs to have computer communication with the Branch Directors near the Fire's edge. There is a possibility to extend the communications by setting up a Wi-Fi Mesh Network with a human mesh node with video camera. He has further complicated this request by asking that the solution be mobile based and constantly on as his branch directors drive.	Set up a mobile mesh network with human mesh node and video camera. Provide internet access to those locations. Use NICS as the situational awareness tool and Skype as the collaboration (chat/video) of choice to communicate over the computer based connections.
13	The agency administrator in Monterey and the Director of the Forest Service in Washington DC are unhappy with the amount of money that is being spent on the fires. They have asked that a conference call be convened to sort out the details.	Create a video conference call for two users in the Camp and two users in an area away from Big Sur (Monterey and the Salinas EOC)
14	The operations chief needs to have computer communication with the branch directors near the fire's edge. He also asked the connection remain active while directors move.	Set up a mobile mesh network. Provide Internet access to those locations. Use Skype to create a Permanent Chat Group as the communication tool of choice over the computer based connections.
15	Increased number of users is has reached the current bandwidth of the all systems in operation. An alternate Satcom link is required	Set up and maintain one of the county VSAT trailers for additional workstations.

THIS PAGE INTENTIONALLY LEFT BLANK

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California

3. Director, NPS HFN
   Brain Steckler
   Naval Postgraduate School
   Monterey, California

4. Chair, Department of Information Sciences
   Dr. Dan Boger
   Naval Postgraduate School
   Monterey, California